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Agricultural Catchments Programme

TIME FOR CLIMATE ACTION

TECHNOLOGY DRIVEN BY SCIENCE

THE VALUE OF SEAWEED

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Our food and environment challenges

People working on the land are used to challenges, ranging from global market fluctuations, to extreme weather, and decades of policies designed to increase agri-food production. However, in recent years policy and public opinion is increasingly shifting towards an emphasis on how sustainably food is produced. Farming is being seen as having a wider role in society in addition to its food production function.

With a rising global population, demand for food is likely to continue to increase, and with more environmental pressure on the planet. For a country with such an important agricultural sector, this is particularly relevant for Ireland and *Food Wise 2025* sets out a ten-year plan for the agri-food area. Water is a key environmental strand and, although Ireland's quality is among the best in Europe, it has remained static in recent years. Despite much progress, more is required. The national River Basin Management Plan outlines the approach that Ireland will take to protect our waters as required under the EU-wide Water Framework Directive.

The Agricultural Catchments Programme (ACP) was developed to address requirements under the Nitrates Directive and to investigate the specific links between intensive agriculture and water quality. It is funded by the Department of Agriculture, Food and the Marine and operated by Teagasc.

For the last ten years the ACP has been operating in intensively farmed study areas in Ireland. Working with approximately 300 farmers in the six catchments, staff are collecting a wide range of data on a near-continuous basis. For example, at the outlet of each catchment, stream phosphorus and nitrogen levels are measured three to four times per hour. The total number of data points runs to many millions per year.

Together with the range of water, ecology, soil, weather, socio-economic and farming data, this is resulting in one of the finest examples of catchments-based environmental research anywhere. The Programme continues to develop linkages with colleagues and organisations in Ireland and the world. Indeed, since the start of the Programme, many colleagues have moved on to other organisations and continue to contribute to efforts to find sustainable solutions to water quality issues in agricultural landscapes. This issue of *TResearch* contains articles from some of these current and former colleagues.

Tom O'Connell
Communications Officer
Agricultural Catchments Programme

Na dúshláin bhia agus chomhshaoil atá romhainn

Daoine a oibríonn ar an talamh, tá siad cleachta le dúshláin. Bíonn na dúshláin sin sa raon idir luaineachtaí sa mhargadh domhanda, adhaimsir agus na beartais atá á saothrú le blianta fada anuas chun táirgeadh agraibhia a mhéadú. Le blianta beaga anuas, áfach, tá beartais agus tuairim an phobail ag díriú níos mó agus níos mó ar cé chomh hinbhuanaithe agus a tháirgtear an bia. Meastar anois go bhfuil ról níos leithne ag an bhfeirmeoireacht sa tsochaí i dteannta na feidhme táirgthe bia a bhaineann léi. Agus an daonra domhanda ag ardú, is dóigh go leanfaidh an t-éileamh ar bhia ag méadú agus go gcuirfidh sé sin tuilleadh brú comhshaoil ar an bpláinéad. Mar gheall ar a thábhachtaí atá an earnáil talmhaíochta sa tír, tá an méid sin an-ábhartha dúinn in Éirinn. Maidir leis sin, leagtar amach sa doiciméad *Food Wise 2025* plean deich mbliana do réimse an agraibhia. Tá uisce ar cheann de na snáitheanna is tábhachtaí ó thaobh an chomhshaoil de agus, cé go bhfuil cáilíocht an uisce in Éirinn i measc na gceann is fearr san Eoraip, is beag athrú atá tagtha uirthi le blianta beaga anuas. Beag beann ar an mórdhul chun cinn a rinneadh cheana féin, is gá dúinn cáilíocht an uisce a fheabhsú tuilleadh. Leagtar amach sa Phlean Náisiúnta Bainistíochta Abhantraí an cur chuige a ghlacfaidh Éire i leith ár n-uiscí a chosaint, mar a cheanglaítear orainn leis an gCreat-treoir Uisce, a bhfuil feidhm aici ar fud an Aontais Eorpaigh.

Forbraíodh an Clár Dobharcheantar Talmhaíochta chun aghaidh a thabhairt ar cheanglais faoin Treoir maidir le Níotráití agus chun imscrúdú a dhéanamh ar na naisc shonracha atá ann idir an diantalmhaíocht agus cáilíocht an uisce. Is í an Roinn Talmhaíochta, Bia agus Mara a chistíonn an clár agus is é Teagasc a oibríonn é.

Le deich mbliana anuas, tá an clár ag oibriú i gceantair staidéir a ndéantar dianfheirmeoireacht orthu in Éirinn. Agus iad ag obair le thart ar 300 feirmeoir sna sé dhobharcheantar, bíonn baill foirne ag bailiú raon leathan sonraí ar bhonn garleanúnach. Ag sceithbhealach gach dobharcheantair, mar shampla, tomhaistear na leibhéil fosfair agus nítrigine sa sruth trí nó ceithre huaire gach uair an chloig. Bailítear na milliúin phointe sonraí gach bliain. Is é an toradh atá air sin, i dteannta na sonraí uisce, éiceolaíochta, ithreach, aimsire, socheacnamaíocha agus feirmeoireachta atá againn, go sealbhaímid anois ceann de na samplaí is breátha ar domhan de thaighde comhshaoil atá bunaithe ar dhobharcheantair. Leanann an clár le naisc a fhorbairt le comhghleacaithe agus eagraíochtaí in Éirinn agus thar lear. Go deimhin, is amhlaidh ó thús an chláir gur bhog a lán comhghleacaithe ar aghaidh chuig eagraíochtaí eile agus go leanann siad le cabhrú linn teacht ar réitigh inbhuanaithe ar shaincheisteanna cháilíocht an uisce i dtírdhreacha talmhaíochta. Tá ailt ó roinnt dár gcomhghleacaithe reatha agus dár n-iarchomhghleacaithe araon le fáil san eagrán seo de *TResearch*.

Tom O'Connell
Oifigeach Cumarsáide
An Clár Dobharcheantar Talmhaíocht

IPSAM 2019

'Harnessing plants for a better society, economy, and environment' was the theme for the 2019 Irish Plant Scientists' Association Meeting (IPSAM), which took place at the Institute of Technology (IT) Carlow recently. IPSAM provides a forum to share research in plant and crop science among the research community across the island of Ireland, as well as fostering practical and applied collaborations with farmers and other industry stakeholders.

The meeting provides a forum for research postgraduate students and postdoctoral scientists to present their findings and promote their future research careers. The meeting included sessions on: biodiversity and invasive species; climate change and abiotic stress; plants for human health; plant growth and development; crop improvement; and, agronomy.

Invited keynote speakers were: Úna FitzPatrick from the National Biodiversity Data Centre; David Walsh-Kemmis from Ballykilcavan Brewing Company; Bill Thomas of The James Hutton Institute, Scotland; and, Fiona Doohan of UCD.

The meeting was jointly organised by enviroCORE at IT Carlow and the Teagasc Crop Science Department in Oak Park, and co-chaired by David Ryan from IT Carlow and Susanne Barth from Teagasc. The IPSAM meeting coincided with the biennial Teagasc Crops Open Day in Oak Park and participants spent the afternoon at Oak Park and explored the research on display. Two Teagasc Walsh Fellow PhD students from Teagasc Oak Park were awarded prizes at the IPSAM meeting.

Diana Elena Bucur won the best student poster presentation prize for her poster 'Population dynamics of *Pyrenopeziza brassicae* (a fungal pathogen of oilseed rape) under Irish field conditions', and Ronan Byrne won the best student oral presentation award for his talk on 'Herbicide resistance in Irish *Avena fatua* (wild oat)'.

IPSAM 2019 attendees before embarking on the bus to a field trip to explore the Teagasc 2019 Crops Open Day at Oak Park.

Researcher profile — Per-Erik Mellander

Per-Erik Mellander has been lead scientist of the Agricultural Catchments Programme in Johnstown Castle since October 2017, and is a Senior Research Officer in catchment science in the Department of Environment, Soils and Land Use, Teagasc. Together with Teagasc colleagues, he leads the Irish action lab of the EU-funded WATERPROTECT (Horizon2020) project, and collaborates in a number of externally funded water quality and Walsh Fellowship projects.

Per-Erik was awarded an MSc in Physical Geography from Uppsala University based on field experiments he made in the National University of Lesotho and a PhD in Environmental Assessment from the Swedish University of Agricultural Sciences based on field experiments in northern Sweden.

Before and during his college studies he worked as a weather observer and meteorologist assistant for the Swedish Meteorological Hydrological Institute. This sparked an ongoing interest in weather and climate, in particular the influence of weather extremes on water quality. Before joining Teagasc he worked with research projects in forested river catchments of northern Sweden and deforested catchments in the Blue Nile Basin in Ethiopia for the Swedish University of Agricultural Sciences and the Mid Sweden University.

In the latter he also lectured in physical geography.

In 2008 he moved from his native Sundsvall in Sweden to join Teagasc and work as a researcher within the Irish Agricultural Catchments Programme. His research interests are concerned with advancing the knowledge of water quality issues for a sustainable environment and food production system under the impacts of increasing population and changing climate.

He specialises in the understanding of hydrological and chemical controls on nutrient (nitrogen and phosphorus) and contaminant loss to water via different pathways within agricultural landscapes.

Per-Erik lives with his wife and two children in the countryside of Wexford, where in his spare time he enjoys playing clarinet and mandolin, and composing music.

European TTO meeting

Teagasc hosted the 12th Plenary Meeting of the European Technology Transfer Offices (TTO) Circle at Ashtown, Dublin, recently. It was attended by over 60 senior representatives of the 30 largest research and technology organisations in Europe, together with representatives from different services of the European Commission. The meeting was organised by the European TTO Circle, a network developed by the European Commission's Joint Research Centre to promote collaboration on the transfer of technologies from research to business and society. This important network has gathered over 200,000 researchers, 35,000 patents, 5,000 pieces of software and 4,000 start-ups in Europe, since it was set up. Teagasc's Head of Technology Transfer, Sean Mulvany, outlined the importance of technology transfer from non-profit research-performing organisations as "aiming to improve and increase socioeconomic activity through licensing our intellectual property so that it is brought to market in a way that realises social and economic potential, aiding the new company formation that will give rise to high-value jobs in communities across the country and making the agritech and agrifood sectors in Ireland more attractive for investment".

Pictured at the meeting were TTO leaders from over 30 of the leading universities and research organisations across the European Union.

Director of Teagasc, Gerry Boyle, said: "We need to engage deeply with the consumer, farmers, companies and policy makers to ensure the ongoing relevance of the research we do to the needs of society. Furthermore, we must ensure every effort is made to get our research out of the organisation and into the hands of those who can bring it into use and deploy it for best benefit, whether that is a company or a farmer".

The Research Field

A new monthly Teagasc podcast to accompany *TResearch* magazine has recently been launched. *The Research Field* is Teagasc's monthly research podcast for everyone interested in agriculture, crops, environment, food, horticulture, forestry and rural development research in Ireland.

Presented by science journalist Sean Duke, with regular contributions from Teagasc's Science Communication and Outreach Officer, Catriona Boyle, the podcast will get out and about and talk to researchers in their various fields. As well as the iTunes platform, *The Research Field* is also available on Soundcloud, Spotify, Google Podcasts or wherever you listen to podcasts.

Industrial hemp conference

The first Irish industrial hemp conference took place in Teagasc Ashtown Conference Centre, Dublin, recently. Teagasc crops researcher John Finnan described hemp as a: "Vigorous crop that can generally out-compete weeds. This is particularly true of the taller varieties; however, the Finola variety is slightly more vulnerable to weed competition. We have not used any herbicides, fungicides and pesticides on our research crops. As with all crops there is a nutritional requirement, which can mainly be met through the application of organic manures".

Kaya O'Riordan of CB1 Botanicals spoke about the opportunity of using industrial hemp to produce bioplastics: "Hemp bioplastic degrades completely after 80 days. Industrial hemp is able to capture approximately 8.9 tonnes of CO_2 per acre. Additional CO_2 sequestration may also occur from finished products such as HempCrete, hemp pellets and bioplastics".

Barry Caslin, Teagasc, said: "There has been a huge interest from farmers and industry representatives in developing a hemp industry in Ireland. Many farmers are seeking land use alternatives, especially in light of the lack of income from the drystock sector. Teagasc has been involved in hemp research since the 1960s, and proved the crop can grow well in Irish soil and climatic conditions".

Patrick O'Mahony from the Food Safety Authority of Ireland described the NOVEL Food Directive and how it affects the production and sale of CBD oil in Ireland: "Generally speaking, hemp oil obtained by cold pressing the seeds or other parts of the hemp plant does not require authorisation. If, however, the CBD/hemp oil is subjected to certain forms of extraction or purification techniques, then a novel food authorisation may be required".

The event was organised by The Hemp Working Group, including hemp organisations, Teagasc and the Irish Farmers' Association, and attended by farmers, academics, Government officials, and business people.

Irish dairying – growing sustainably

Thousands of farmers attending the Teagasc Dairy Open Day, Moorepark 2019, heard how the Irish dairy industry has been transformed, with exports of Irish dairy products and ingredients increasing from an average of €1.84 billion from 2007 to 2009, to over €4 billion in 2018. Milk production in Ireland has increased to 7.57 billion litres in 2018, and current indications are that milk production in 2019 could reach eight billion litres.

Director of Teagasc, Gerry Boyle, warned dairy farmers that the Irish dairy industry is currently facing a number of key challenges, namely: climate change; water quality; remaining competitive; access to markets; and, availability of skilled labour: "The challenge is to grow the business sustainably. In relation to climate change, Teagasc has produced guidelines for the dairy sector, identifying key actions that need to be undertaken to reduce the industry's environmental footprint".

Teagasc researcher Stephen Butler outlined the results of a recent sexed semen trial at the event. He said that the levels of fertility performance obtained in the study makes sexed semen a viable strategy for generating replacement heifers on commercial farms, but more work is needed to identify the reasons for poor performance with sexed semen in a subset of herds that can achieve excellent performance with conventional semen.

Attendees at the recent Teagasc Dairy Open Day at Moorepark.

Details of the study, and a comprehensive booklet outlining all the latest research and advice presented at the Open Day, are available at https://www.teagasc.ie/publications/.

The overall sponsor of the Open Day was FBD Insurance, with additional support from Ornua and Ulster Bank.

Dairy research in the *IJAFR*

The *Irish Journal of Agricultural and Food Research* (*IJAFR*) is an open-access peer-reviewed scientific journal published by Teagasc since 1961. Sinead McParland, a researcher at Teagasc Moorepark, recently published a paper entitled 'Prediction of 24-hour milk yield and composition in dairy cows from a single part-day yield and sample,' which, based on a request by industry, evaluated the accuracy of predicting 24-hour milk yield and composition from a single morning or evening milk weight and composition. The study found that a single morning sample is useful to predict 24-hour milk yield and composition when the milking interval is known. The work was done in association with the Irish Cattle Breeding Federation (ICBF), Munster AI Group and Progressive Genetics; the study also revised the current predictions from two milk weights and a single milk sample used in almost all milk recordings tests in Ireland.

Recent papers in the *Journal* can be viewed, or new papers submitted, on the *IJAFR* website: http://bit.ly/IJAFR_Teagasc.

Sustainable crop production

The carbon footprint of the main tillage crops in Ireland is already low at between 0.3 and 0.6 kg CO_2-equivalents per kg grain, but opportunities to reduce it further were highlighted at the Crops and Spreaders Open Day in Teagasc Oak Park, Carlow, recently.

Head of the Teagasc Crops, Environment and Land Use Programme, John Spink, said: "Minimising the impact of farming on the environment is gaining increasing importance and reducing nutrient losses delivers benefits for both the farmer and the environment. To achieve this you need to get the correct rate and timing of fertiliser in the right place – application is critical irrespective of fertiliser type. Today's event highlights the importance of machine settings and the opportunities using GPS to achieve more precise application".

Tillage farmers were advised of the benefits of using manures to build soil health in tillage systems by improving soil organic matter. The opportunities to make better use of crop rotations and the options for winter cover crops were also highlighted.

Loss of crop protection products is now a fact of life and emphasises the need for integrated pest management (IPM). Ongoing work on aphid control and adjustment of sowing dates for both winter and spring cereals was highlighted, as was the extensive research work carried out at Oak Park on Septoria, which is the most economically destructive disease of Irish winter wheat. The importance of bees as pollinators of food crops such as peas, beans, apples and soft fruit was stressed at the Open Day and farmers were encouraged to allow hedgerows to flower and leave field margins to flower. The Teagasc Forestry Department spoke about the need to make "room for trees on your farm," and highlighted how trees can contribute as part of a whole farm approach. The information booklet from the Open Day is available on www.teagasc.ie.

The Teagasc Crops and Spreaders Open Day focused on ways to reduce the carbon footprint of tillage crops.

Weather affected 2018 farm incomes

The extent of the financial impact of adverse weather on Irish farm incomes in 2018 is evident from newly released data from the Teagasc National Farm Survey. A long winter followed by an extremely dry summer seriously affected grass growth. As a result, on grassland farms there was a substantial increase in the volume of purchased feed and fodder required to make up for the shortfall in grass production, with average feed expenditure up 34%. The need to increase fodder stocks resulted in increased spending on fertiliser, machinery contracting and fuel. The combination of these factors pushed production costs strongly upwards.

The extent to which weather had an impact on individual farm incomes in 2018 depended on factors specific to each farm, including local weather, farm type, soil type, stocking rate, and the mix of winter and spring crops sown. Good late season grass growth and an extended silage making campaign helped to avert even steeper increases in production costs late in the year and stemmed the erosion in farm incomes. Average family farm income on Cattle Rearing farms dipped to an estimated €8,318 in 2018, a reduction of 22% on the €10,642 in 2017. Cattle Other farms, which comprise a range of cattle production systems, also experienced an income drop. Average Cattle Other farm income in 2018 was €14,408, a reduction of 11% on the 2017 figure. According to Teagasc economist Emma Dillon, Dairy farms incurred the largest income reductions in 2018, with average dairy farm income falling by 31% to €61,273, compared with the 2017 level of €88,829. Sheep farms also experienced an income reduction in 2018, with higher than normal levels of feed and fertiliser use.

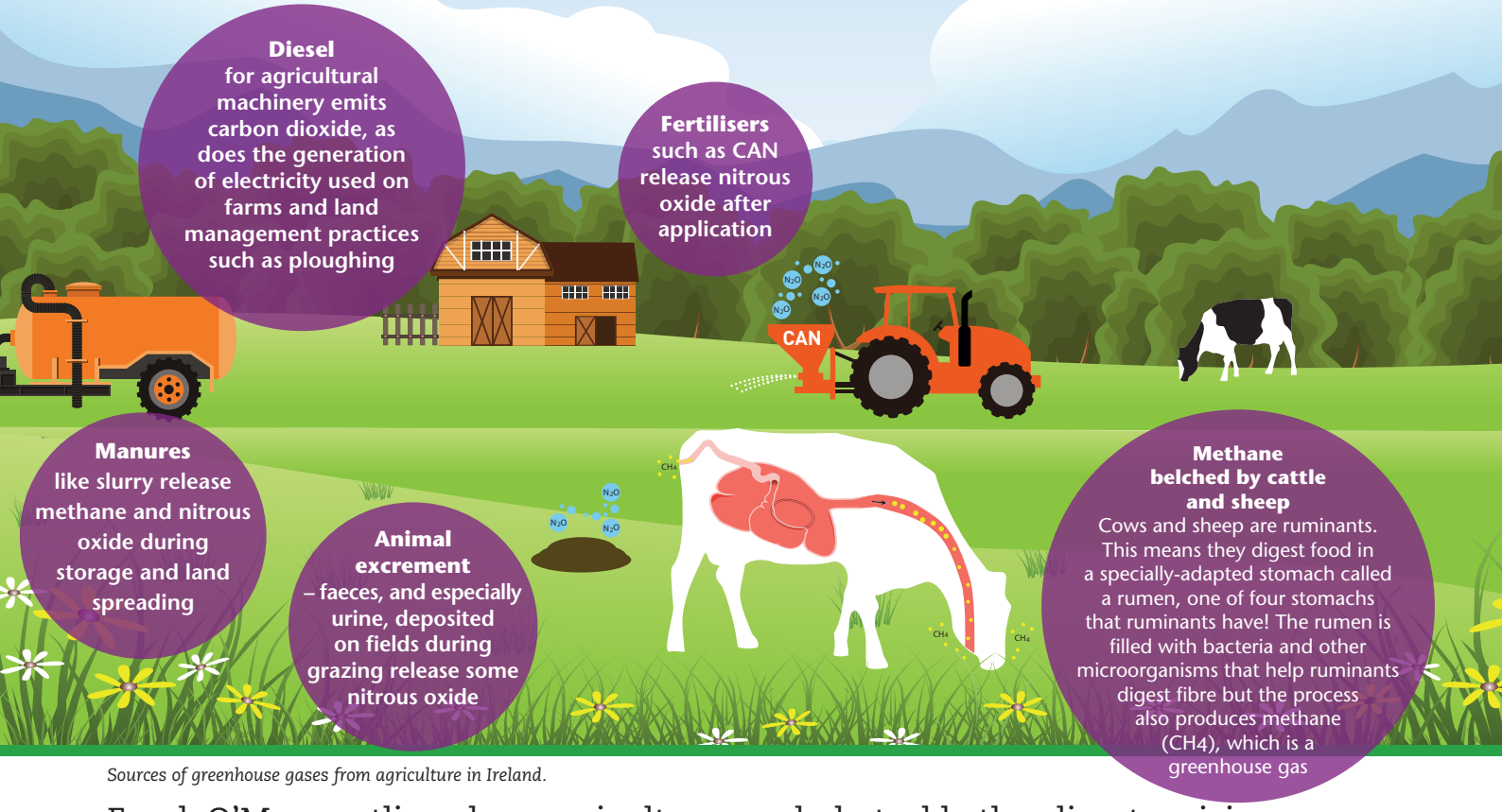
Across the farm sector as a whole, the average family farm income in 2018 declined by 21%, dropping from €29,774 in 2017 to €23,483. However, the average on individual farm systems continues to vary greatly.

Agri benchmark Namibia

Teagasc economist Anne Kinsella participated in a panel discussion on 'Productivity growth and sustainable development in Africa – preconditions and ingredients' at the *agri benchmark* Beef and Sheep Conference in Namibia recently. *Agri benchmark* is a global, non-profit network of agricultural economists, advisors, producers and specialists in key sectors of agricultural and horticultural value chains.

As Africa is the continent where most of the population demand and growth will occur in the future, panellists were asked to discuss how the livestock sector in Africa could develop in a sustainable way and which lessons could be learned from other countries. The Irish experience was looked upon as a good example of what could be achieved, says Anne: "Improving the skill levels of farmers and maximising adoption of best practice has been achieved in Ireland through the delivery of training and facilitation of farmer discussion groups on best practice through the advisory/extension service. It is not only a top-down prescriptive approach. One of the most important elements in the whole process is in getting the farmers on board and developing their knowledge of best practice. An increasing number of Irish farmers are recognising that sustainable and efficient farming go hand in hand".

Time for climate action



Sources of greenhouse gases from agriculture in Ireland.

Frank O'Mara outlines how agriculture can help tackle the climate crisis.

Following on from the report of the Oireachtas Joint Committee on Climate Action, the Government has published a new Climate Action Plan to tackle Ireland's rising greenhouse gas (GHG) emissions and to comply with our international obligations. The new plan includes target emission cuts for all sectors, including agriculture. Ireland is currently not on track to meet its national targets: the target for the period up to 2020 (20 % below 2005 levels) will not be met without buying emission credits at significant cost to the taxpayer. The target for the following decade is to reduce emissions further (30 % below 2005 by 2030) and as our emissions are rising rather than falling, there is potential for further large bills post 2030. In addition to complying with international agreements, consumers and food retailers are demanding cuts in carbon emissions from food production.

Agriculture emission targets

So what are the targets for agriculture in the new Plan? Emissions of GHGs were 18.7 million tonnes (mt) of CO_2-equivalents in 2005, which is the base year. More recent figures for 2017 show emissions at 20.2 mt and Teagasc projections for 2030 suggest a figure of 21 mt, with a range around this figure depending on how the national bovine herd changes. One could ask why agricultural emissions are rising, given that our farming systems are very sustainable, and mainly based on grazed grass, allowing us to produce milk and meat with a low carbon footprint. For instance, in one important EU study (Leip *et al.*, 2010), we had the joint lowest carbon footprint for our milk (joint with Austria). The reason for the rise in total emissions is that emissions are very closely related to the size of the national herd, and we have a larger cattle herd since the end of milk quotas. The target for agriculture in the new plan is to get emissions back to a range of 17.5-19 mt by 2030, which is a cut of 10-15 % on the projected levels in 2030 relative to 2017. The agri sector will also deliver 2.68 mt per year through land use (forestry and soil management).

Actions for agriculture

So will we have to cut the national herd to reach our emission reduction targets? The answer is no, as long as we take action to reduce emissions. The target set for agriculture is very challenging, but Teagasc has been researching methods to reduce emissions and collaborating with the best scientists in our universities and internationally, and there are now several practical solutions available. These have all been published in a technical paper by Lanigan *et al.* (2018) called the Teagasc Marginal Abatement Cost Curve (MACC), which sets out 26 actions that farmers can take

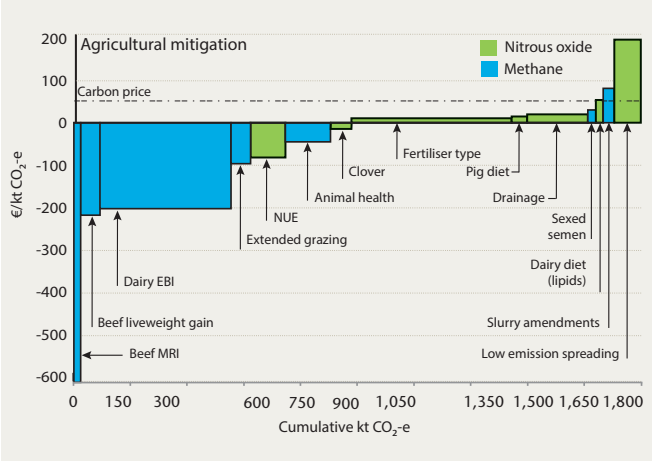


FIGURE 1: The Teagasc Marginal Abatement Cost Curve (MACC). Actions on the left of the MACC graph reduce emissions and save money at the same time (win-win); items on the right also reduce emissions but there is a cost involved.

across agricultural production, carbon abatement from land use such as forestry and soil management, and providing renewable alternatives to fossil fuels (**Figure 1**). The main agricultural production measures can be seen in **Figure 2** and these include:

- continued good, efficient farming (improving Economic Breeding Index [EBI] and beef genetic merit, better grassland utilisation and incorporation of clover into grassland, getting soil pH right, etc.);
- switching to a form of urea fertiliser, known as protected urea, which significantly cuts emissions of nitrous oxide compared to calcium ammonium nitrate (CAN); and,
- spreading as much slurry as possible in the spring, and using a low-emissions way of spreading it, such as the trailing shoe or trailing hose.

Improving farm sustainability

In the case of both protected urea and low emissions slurry spreading, greater value is achieved from the fertiliser or manure as less of the nitrogen is lost to the atmosphere and, therefore, fertiliser usage and bills can be cut. Importantly, forestry and the way we manage our peat soils can make a major contribution by sequestering carbon, with up to 2.68 mt per year allowed to be included in carbon offset to 2030. Both can be sensitive issues, which need to be handled correctly, but undoubtedly they are important in this debate. All farmers can also make a contribution through the planting of hedgerows and native woodlands. Another area where farmers can make a contribution is through provision of bio or renewable energy, though this has been a slow starter to date.

Time for climate action

So can we reach the target? It is ambitious and change is often slow and difficult to achieve, but the targets will have to be achieved. In agriculture, a whole of sector response will be necessary and policy will need to support change. The new Common Agricultural Policy (CAP) will have greater targeting of resources (40 %) to climate-friendly practices. Teagasc will initiate a major intensive advisory campaign around

FIGURE 2: 7 Steps to Improving Farm Sustainability.

implementation of the measures in the MACC and will work closely with farmers and all sections of the industry, Bord Bia and the Department of Agriculture, Food and the Marine in this endeavour. The sooner the changes are made, the better, as the emissions reduction is in place for a longer period and the savings have longer to add up. In addition, we will continue our research effort to find new practical solutions that are compatible with good farming. Given that we are part of a global food system supplying food to a growing population, it is vital that we find ways to grow food production and reduce emissions.

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Identifying farmers' perceptions of farm accident causes

Machinery/vehicles ranked highest for accident causation.

TEAGASC research reveals that future health and safety communications to farmers should focus on objective data.

Improving the safety record of the farming sector is a key goal of both State and farming organisations in Ireland. Knowing how farmers conceptualise accident causation is crucial to guide effective communications strategies for farm safety. This article describes the opinions of a large sample of Irish farmers on accident causation. The article is framed in the context of contemporary accident causation theory.

Accident causation theory

An accident is defined as an event that leads to bodily injury. The public health model (PHM) of accident causation conceptualises an accident as occurring due to multiple interacting physical and human factors (Runyan, 2003). In this model, a transfer of energy is the vector that causes injury and where a time dimension leads to all factors occurring in the same time and place. Runyan (2003) proposed that the social-ecologic framework as described by Bronfenbrenner (1979) enhances the PHM model (**Figure 1**) of accident causation, as it defines various levels of the social environment in concentric nested roles of intrapersonal and interpersonal factors, as well as institutional and cultural elements, which are influential on persons related to accident prevention. Regarding accident prevention models, the conceptual work of Haddon (1980) indicates that accidents are prevented by applying multi-faceted approaches, including both physical and organisational measures.

Study methods

Teagasc provides half-day training on the completion of the Health and Safety Authority (HSA) Risk Assessment Document (RAD) to farmers. During the piloting phase of these training courses, participants were asked to individually rank their opinion of the causes of farm accidents on a ranking card from first to fifth. An objective of this exercise was to gain information on farmers' perceptions of farm accident causation.

In total, 1,151 farmers completed the ranking cards during the training, with a total of 5,029 accident causes being identified. To analyse the data, first-ranked accident causes were each allocated a weighting of five, and sequentially each rank was allocated a lower weighting, with fifth-ranked cases allocated a weighting of one. First-ranked scores are taken to indicate what is most prominent in farmers' minds in relation to accident causation, while the total score provides a more broadly based ranking with all scores included. Data collected was compared with objective fatal farm accident data for the previous ten years presented in the pilot RAD (HSA, 2006).

Study findings

The study findings presented in **Table 1** indicate that 92 % of first-ranked scores were related to 'machinery/vehicles' (55 %), 'organisational' (27 %) and 'livestock' (10 %). For total scores, six scores contributed to 96.5 % of the total, with 'slurry related', 'trips, falls, buildings related' and 'electrical' being the additional causes. Notably, 'children', as associated with farm accident occurrence, was ranked low at 1 % of first-ranked causes, while the issue of older farmers having a farm accident received no ranking whatsoever. Within the 'machinery/vehicles' category, accidents associated with 'power take off (PTO)/power shafts' accounted for 56% of the first-ranked and 46.9 % of all-ranked accident causes. Within the 'organisational' category, 'carelessness and rushing' accounted for

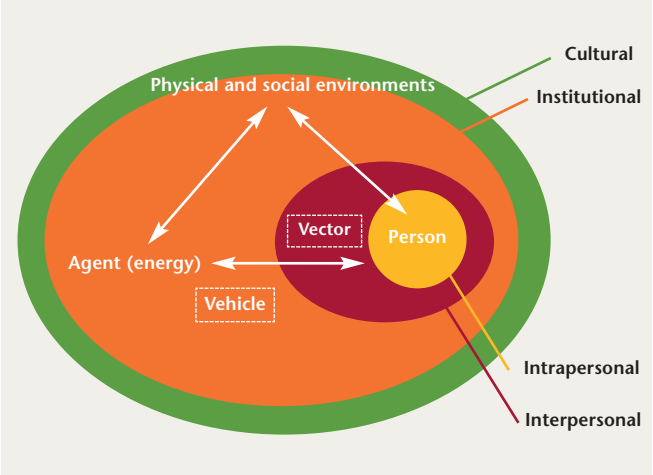

FIGURE 1: Integration of the public health model and social-ecologic framework of accident causation. Source: Runyan (2003).

84.1 % of first-ranked and 65.5 % of all-ranked causes.

The findings of this study indicate that farmers attributed farm accidents mainly to a number of physical causes and work organisation issues, which is in accord with accident causation theory. However, the data presented in **Table 1** indicates that participants' perceptions of accident causation were not in line with the actual causes of fatal farm accidents as described in the pilot RAD. For instance, data from the pilot RAD indicated that 32 % of fatal farm accidents in the 'vehicle and machinery category' were entanglements in PTO/power drives, while ranking card responses attributed almost 47 % of accidents to this cause. Furthermore, the pilot RAD indicated that 20 % and 38 % of accidents, respectively, were associated with children and older farmers (over 65 years old).

Conclusion

Overall, this study indicates that farmer perceptions of accident causation are broadly based; however, they were inaccurate when compared with objective fatal farm accident data. Thus the study suggests that communicating accurate and contemporary occupational safety and health (OSH) messages to farmers based on objective data is likely to be a crucial requirement to make progress with accident prevention in agriculture.

Further reading

This article is based on the recently published paper: McNamara, J., Griffin, P., Phelan, J., Field, W.E. and Kinsella, J. (2019). 'Farm health and safety adoption through engineering and behaviour change', *Agronomy Research*, 17. Available from: https://doi.org/10.15159/AR.19.151.

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Table 1: Ranking of causes of farm accidents in order of importance.

Accident causes	Ranking order First (%)	Total (%)
Machinery/vehicles	55	31.6
Organisational	27	21.3
Livestock	10	18.4
Slurry related	4	13.2
Trips, falls, buildings related	2	7.2
Electrical	1	4.8
Children	1	1.3
Chemicals	0	0.7
Other	0	1.5
Total	**100**	**100**

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Phosphorus management for improved water quality

A TEAGASC study dug deep into the factors affecting phosphorus levels on two catchments in Louth and Wexford.

Irish soil fertility levels have remained well below optimum requirements for productive agriculture, with 60 % of soils deficient in phosphorus (P). This is limiting the ability of many Irish farms to contribute to national expansion targets set out under Food Wise 2025. P is a primary soil nutrient and plays a vital role in stimulating early plant development. However, it is also a key limiting nutrient for algal growth in rivers and lakes; therefore, when elevated P concentrations enter freshwater systems, the water quality declines. This is impacting on Ireland's goal to improve water quality and achieve its EU Water Framework Directive targets.

Under the EU Nitrates Directive, the Good Agricultural Practice (GAP) regulation measures (SI 605 of 2017) are implemented to reduce the risk of P losses to water bodies from agriculture. Since 2009, the Agricultural Catchments Programme (ACP) has been monitoring and evaluating the impact of these GAP measures on achieving good water quality, while sustaining or increasing farm viability across a range of soil types, farm enterprises and intensities.

Farm vs field scale

Nutrient management planning (NMP) is a GAP measure designed to reduce high levels of soil P. It is typically conducted at the whole-farm scale, in which maximum farm P fertiliser application limits are set according to the farms' crop types, stocking rate and soil test P (STP) levels. This farm-scale approach to manage STP levels by either building up deficient soils (Index 1 and 2) or drawing down high STP soils (Index 4) towards optimum (Index 3) is related to the P balances operating at the farm scale. A P balance is the difference between P inputs (i.e., manures and animal feed) and P outputs (i.e., meat, milk and arable crops) in the farm system. However, hotspots of agronomic underperformance and/or environmental risk that are occurring within the farm may not be clearly identifiable.

A catchments study

To identify such hidden trends and account for P distribution, the ACP recently published a study (McDonald *et al.*, 2019) that carried out a detailed audit of field-scale balances and assessed STP trends within two (<11.5 km^2) catchments (Castledockrell, Co. Wexford and Dunleer, Co. Louth) of mixed land use over a four-year period (2010-2013). Farm management data supplied from the ACP farmers was utilised to calculate field P inputs off-takes, and P balances, using a similar balance calculation to that described for determining farm gate balances. In this study the same catchment fields were sampled and analysed for STP at the start of the study period (2009/2010) and this was repeated four years later (2013/2014). This facilitated the calculation of soil P balances, i.e., field P balance minus the P build-up requirement of the initial STP.

Field P: trends and variability

Driven by increased chemical fertiliser P inputs, the field balances in the Castledockrell catchment had an average surplus P ranging from 1.9 kg/ha per year in 2011 to 7.5 kg/ha per year in 2013. However, between the study period 2010 to 2013, the average STP levels declined as the area deficient in STP increased from 60 % to 67 %, with the area of excessive soil P concentrations (Index 4) decreasing

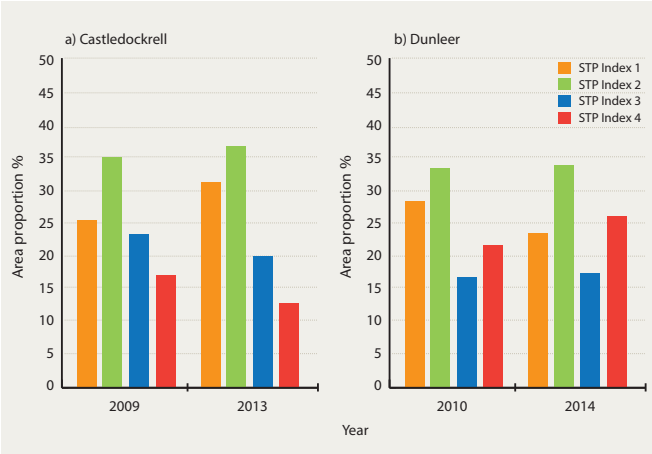

FIGURE 1: Percentage area of soils within each STP index (1-4) in the (a) Castledockrell and (b) Dunleer catchments between 2009 and 2013/2014.

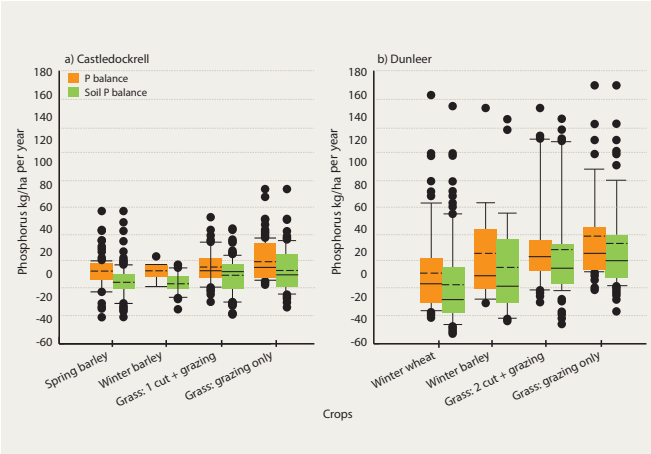

FIGURE 2: Distribution of field and soil P balances of the four main crop types across the (a) Castledockrell and (b) Dunleer catchments. Dotted line represents the average.

by 8 % (**Figure 1**). Similarly, in Dunleer the average annual fertiliser P inputs increased the surplus field P from -0.42 kg/ha per year in 2010 to 25.5 kg/ha per year in 2013, but the area of excessive soil P concentrations increased by 4 % (**Figure 1**). In part, this increase is attributed to some fields receiving excess applications of organic manures above crop requirements. Examination of the average field and soil P balances across the main crop types in both these catchments found that there was a large variability of P management across and within crop type (**Figure 2**). While there was an indication of a response to GAP measures in Castledockrell, for both catchments it is evident that the distribution of P sources within farms was poor, as P inputs often did not match crop and soil P requirements at the field scale.

Future implications and recommendations

Farm gate balances are important indicators for recognising changes in nutrients at the farm scale. However, this study demonstrates the need to account for P balance at the field and even sub-field scale to help identify where P can be retained or lost from the agricultural landscape. This study highlights the need for improved supports to enhance knowledge transfer mechanisms that can deliver better farm and soil-specific NMP strategies for farmers. Emphasis is also needed on better distribution of organic manures within farms, especially in catchments that neighbour confined units such as pig, poultry and mushroom enterprises. Without these considerations, achieving the dual benefits of improvement to water quality targets and increased crop output from the landscape may become restricted.

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Live long and phosphor

A TEAGASC study examined the factors influencing phosphorus use efficiency on Irish agricultural catchment farms, how to get the most from it, and keep it from our water bodies.

Phosphorus (P), nitrogen (N) and potassium (K) are essential nutrients for plant growth and have been used by the agricultural sector to increase crop yields for many decades. P is a finite resource, and hence its efficient usage is important for sustainable food production and food security. However, excessive P applied to land can transfer to watercourses and lead to adverse water quality outcomes. Therefore, finding a balance between applying the correct amount of P to ensure optimum crop yield, encouraging efficient use of this finite reserve, and protecting the natural capital of waterbodies is a major challenge for land managers, researchers and policy makers.

The optimum use of P at farm level is determined by a range of factors including biophysical, farm management and socioeconomic characteristics (**Figure 1**). The focus of this study was to investigate the land management and socioeconomic factors that influence the movement towards optimum soil P on Agricultural Catchment Programme (ACP) farms. ACP farms in six catchment locations had their fields sampled and analysed according to agronomic standards for available P, soil test P (STP), between 2009 and 2011, and the same fields were sampled again three to four years later.

Optimum soil P fertility levels are based on a soil P index system. Soils are at an optimum P status if the soil test results fall into STP Index 3 (**Table 1**). For soils in STP Index 3 there is enough P available for crop and animal requirements, and the farmer will only need to replace the nutrients being removed in products (meat/milk/grain) to maintain ideal soil P levels. STP Index 1 and 2 soils indicate a very low and low P supply in the soil, and require additional P to increase the fertility levels of the soil and replace the P being removed in products. Index 4 soils have a high P supply and present an opportunity to save money on fertiliser inputs by utilising legacy P soil reserves.

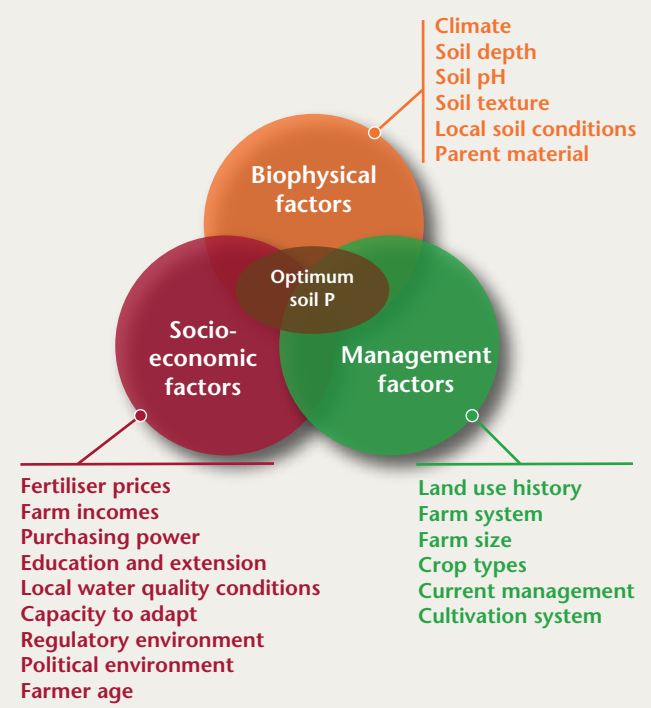

FIGURE 1: Factors influencing the achievement of optimum soil P.

Table 1: P index system.

Soil P Index	Soil P ranges (mg/L Morgan's extractable P)		
	Grassland	Other crops	Index description
1	1.1-3.0	1.1-3.0	Very low
2	3.2-5.0	3.2-6.0	Low
3	5.1-8.0	–10.0	Optimum
4	> 8.0	> 10.0	High

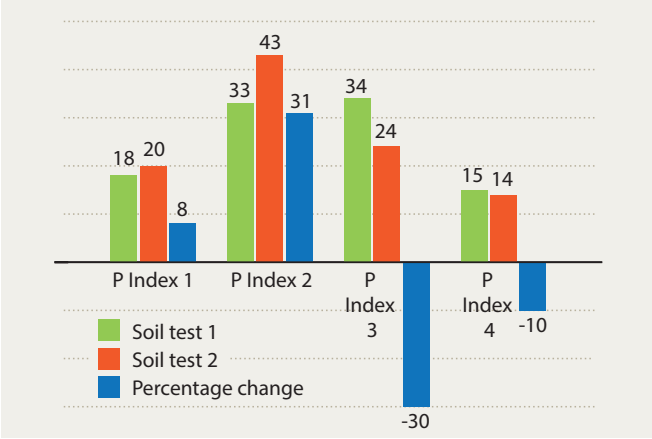

FIGURE 2: The percentage of farms at P index levels in soil test 1 and soil test 2, and the percentage change between the two soil tests (N = 132).

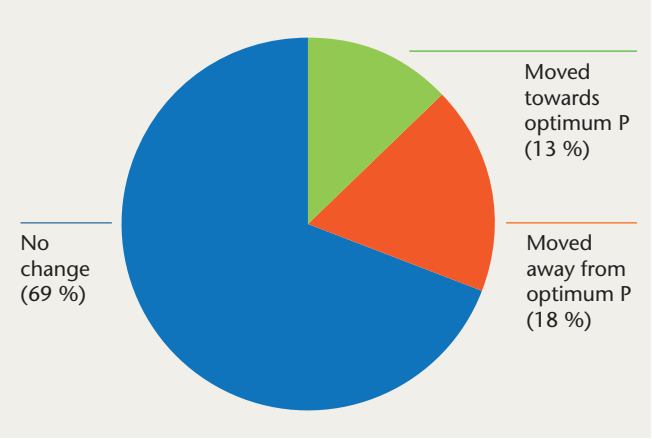

FIGURE 3: The direction of the changes in soil P status.

Results

Figure 2 represents the average farm soil P levels across the soil P index categories and the percentage changes between the first and second soil tests. The greatest percentage changes occurred between STP Index 2 and STP Index 3, with a drop of 31 % in optimum STP Index 3 levels and an increase of 30 % in STP Index 2. There was also a 10 % drop in the number of farms with STP Index 4 and a slight increase of 8 % in STP Index 1 farms. From an environmental risk perspective, this outcome tends to suggest a reduced risk of transfer to the aquatic environment; however, the decline in soil fertility levels may have agronomic productivity consequences.

Figure 3 represents the direction of change in STP index levels. On 69 % of farms there was no change in soil P levels between the two soil test periods. Movement towards the optimum P level is defined as a movement in average farm soil P fertility levels towards Index 3. To increase soil P levels from Index 1 or Index 2 to Index 3 can be expensive, as it requires additional fertilisers (chemical or organic). Decreasing soil P levels from Index 4 is a cost saving, because the farmer can utilise legacy P reserves in the soil and reduce the amount of chemical fertiliser applied. Therefore, the costs associated with a positive movement in soil fertility P levels are different for these two groups of farmers. Overall, 13 % of farms moved towards optimum P Index 3 between the two soil test periods, while 18 % moved away from optimum P levels. The results of a regression analysis suggest that the factors in **Table 2** have a significant influence on the movement towards optimum P status: a plus sign indicates that these farms/farmers are more likely to move towards optimum P status; and, a negative sign indicates that these farms/farmers are less likely to move towards optimum P status.

Table 2: Factors with a significant influence on P use efficiencies.

Variable	Direction of the influence
Specialist tillage farms	+
Farms at P Index 4	+
Farmers who have a nutrient management plan	+
Farmers who have more advisory contact	+
Bigger farms	+
Farmers who work more hours off farm	-
Farms with higher stocking rates	-

Conclusions

Reaching and maintaining optimum P soil fertility levels is a complex and difficult task for farmers and depends on biophysical, farm management and socioeconomic factors. A significant finding of this study is that farms that were previously P Index 4, which is above the optimum level, were more likely to move towards optimum P Index 3 than farms at low index P levels. A reduction in high soil P levels is a positive outcome in terms of risk of nutrient transfer to watercourses and improved sustainability of production.

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The beast from the east: how water quality weathered the storm

Long-term TEAGASC research enabled the gathering of the first temporal resolution record of water quality in Ireland during a snowstorm.

For many in Ireland, severe weather and its effects were the defining features of 2018, including the most significant snowstorm since 2010 (Met Éireann, 2019). Between February 27 and March 5 Tropical Storm Emma, a low-pressure system approaching from the south west, interacted with a severe polar front nicknamed 'The Beast from the East', to produce heavy snowfall focussed on the south east of Ireland. Direct impacts to Irish farms included structural damage, crop loss, livestock fatalities and increased demand on fodder reserves. Long-term monitoring in catchments participating in the Teagasc Agricultural Catchments Programme (ACP) has provided insight into the effects on water quality.

Catchment monitoring

Two catchments located in Co. Wexford, less than 20 km apart and in the region that received the most intense effects of the snowstorm, were monitored as part of the long-term research programme. Castledockrell is a well-drained arable catchment (1,120 ha), with a brown earth soil type. Barley production predominates and the annual average rainfall is 944 mm. Ballycanew is a poorly drained grassland catchment (1,190 ha), consisting of gley soil, with an annual average rainfall of 1,013 mm. Overland flow pathways predominate in this catchment. Each catchment is equipped with a weather station and a bankside analyser at the river outlet. Each analyser monitors total phosphorus (TP), total reactive P (TRP) and total oxygenated nitrogen (TON) at ten-minute intervals, as well as recording stream discharge. Due to impassable road conditions, measurements of snow depth were not possible in either catchment; however, Met Éireann reported maximum depths at four sites in Wexford of 38-42 cm on March 3, with significant drifting widely observed.

Air and water temperature

The event consisted of two phases; a snowfall phase between February 27 and March 1, and a thaw beginning on March 2. In both catchments, air temperature fell below 0°C between February 27 and March 3, and exhibited similar patterns; however, the response in water temperature differed. Stream temperatures never dropped below 0°C in the well-drained arable catchment. Conversely, the poorly drained grassland stream was below 0°C between February 28 and March 4, and warmed more slowly during the subsequent week. This reflects the dominant contribution of groundwater in the well-drained catchment, as opposed to the more overland flow-dominated poorly drained catchment. Groundwater is buffered from sharp changes in air temperature and so maintains a more moderate temperature.

Stream discharge

Stream discharge declined in both catchments during the snowfall period. This is not surprising as the precipitation was effectively immobilised in snow cover. Stream discharge in both catchments began to climb on March 2, corresponding to the beginning of air temperature increases. Increases in discharge were greater and more rapid in the poorly drained catchment due to its limited infiltration capacity and propensity for runoff. Thomas *et al.* (2017) calculated that 79 % of soils in this catchment generate overland flow, compared to 50 % in the well-drained catchment.

Stream nutrients

Both catchments exhibited above average nitrate nitrogen (NO_3-N) concentrations prior to the event as a result of prolonged saturation during spring and groundwater flushing throughout the winter

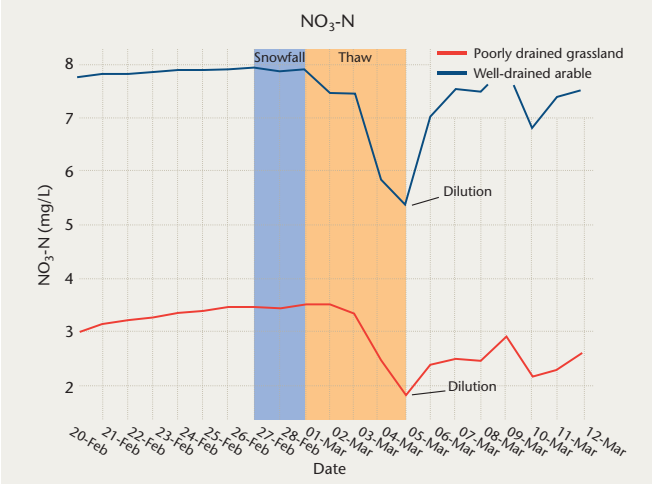

FIGURE 1: Stream NO_3-N concentrations.

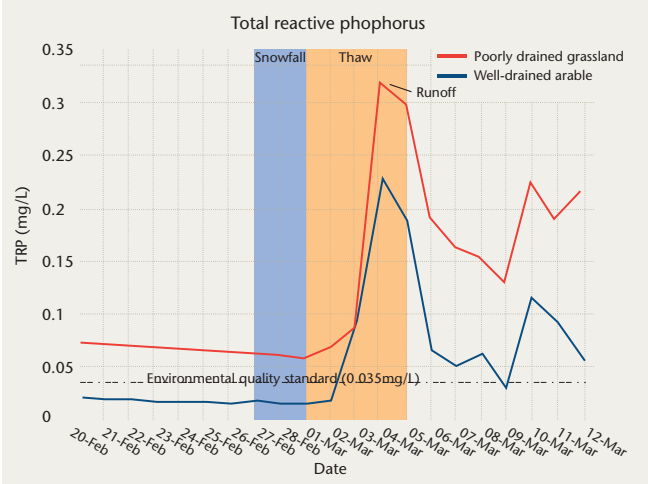

FIGURE 2: Stream TRP concentrations.

(**Figure 1**). These concentrations arise via the groundwater pathway, and were diluted by the addition of meltwater from March 3 and 4. TRP was marginally below average concentrations in both catchments prior to the snowfall (**Figure 2**). In the well-drained catchment, TRP spiked to 0.12 mg/L on March 3, and rapidly declined over the subsequent 48 hours. Particulate P was slower to arrive at the stream, peaking on March 4. This suggests physical immobilisation of particles beneath the snow cover. Analysis of high-frequency hydrochemistry data indicated rapid thaw and exhaustion of P sources near to the stream, followed by longer flow pathways from more distant sources. As these well-drained soils were not saturated throughout the spring, nutrients would have been applied once the closed period ended and a limited amount of bare soil was awaiting tillage.

Higher and more prolonged elevations in TRP were observed in the poorly drained grassland, occurring from March 4 onwards. These concentrations exceeded the environmental quality standard of 0.035 mg/L, and remained elevated throughout the thaw period. The slower mobilisation of P in this catchment suggests that sources were more distant from the receptor. This may reflect low soil moisture deficits in the near-stream areas prior to the event, with limited opportunity for fertiliser application after the closed period ended. However, once thaw began there was greater mobilisation of P from the soil surface throughout the catchment. Thereafter, high levels of P loss were observed, as is typical of soils within this drainage class, which generates high levels of overland flow and has short pathways to the stream.

Recommendations

Compared to severe rainfall, snow accumulation exceeding 10 cm is relatively infrequent, occurring roughly every five to 18 years in inland areas and more rarely along the coast. Nevertheless, it influences stream nutrient concentrations and has implications for land and nutrient management. Heavy snowfall should be treated similarly to rainfall forecasts as regards nutrient loss; however, effects are likely to be delayed due to immobilisation of water as snow. Antecedent soil moisture conditions influence both the propensity for runoff and land management. Decisions regarding fertiliser application should take snowfall forecasts into account and should avoid application near watercourses and on saturated or highly sloping ground. Breaking the pathway is crucial, as this prevents transport of nutrients in more distant areas of the catchment. This research presents the first high temporal resolution record of water quality in Ireland during a snowstorm and was made possible due to the long-term monitoring in operation in these study catchments.

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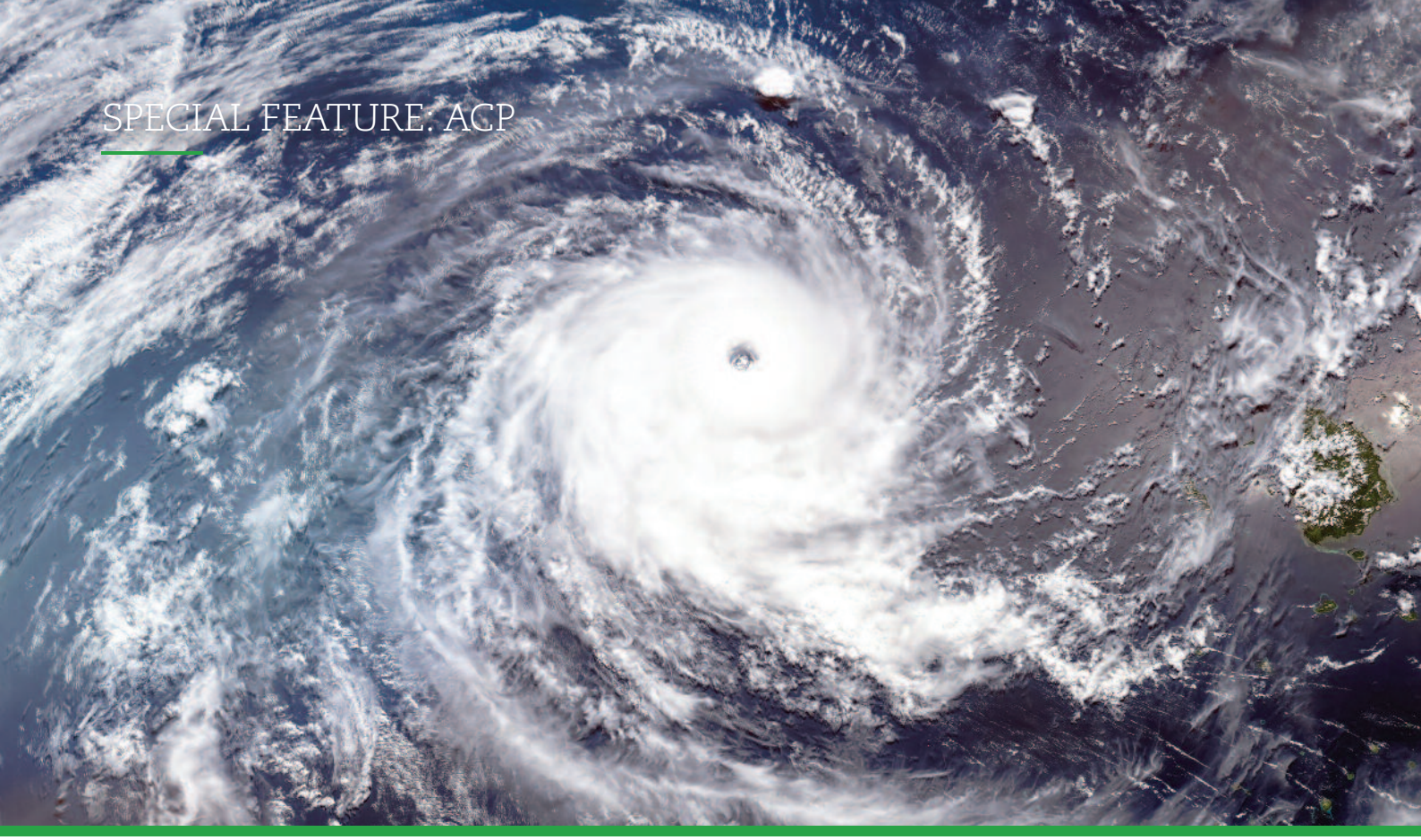

Climate phenomena and catchment water quality

Collaborative TEAGASC research studied the effects of the North Atlantic Oscillation on water quality in Ireland and elsewhere in north-west Europe.

Do climate and weather conditions alter the effectiveness of diffuse pollution measures? Agricultural Catchments Programme (ACP) researchers say they likely do across north-west Europe and may both help and hinder water quality management. The Water Framework Directive requires EU member states to protect all water resources and make improvements where these are needed. Agriculture is a key pressure, mainly due to the risk of phosphorus (P) and nitrogen (N) losses from land, especially during wet weather, and which can lead to water quality problems. In Ireland, measures to reduce these pressures from agriculture are mostly contained in the Nitrates Action Programme and there is an expectation that, as time passes, the measures will have a positive impact on water quality.

But variations in weather conditions may influence how successful these measures are and extremes such as floods and droughts are important to consider.

Climate oscillations

But variations in weather conditions may influence how successful these measures are and extremes such as floods and droughts are important to consider. There are also trends in weather conditions that are linked to longer-term climate systems over the major oceans and these may affect our weather from year to year and over decades. One such climate system is the North Atlantic Oscillation (NAO). This is a difference in atmospheric pressure between the north and mid-Atlantic latitudes and is described by a simple index. In positive phases of the NAO index, weather in north-west Europe is associated with elevated air temperatures in summer and more frequent large rainfall events in winter. The opposite is true when the differences in atmospheric pressure flip to negative phases of the NAO. These phases can grow and diminish over decadal time scales and influence weather patterns over wide areas. Since approximately 2009, the annual average NAO index has sharply increased to a positive phase (**Figure 1**).
As weather conditions influence both soil temperature and the way in which rainwater flows over and through agricultural soils – conditions important for moving nutrients from land to water – we investigated links to the NAO (Mellander *et al.*, 2018). This type of analysis can only be made with a complete dataset of water quality measurements that covers all stages of

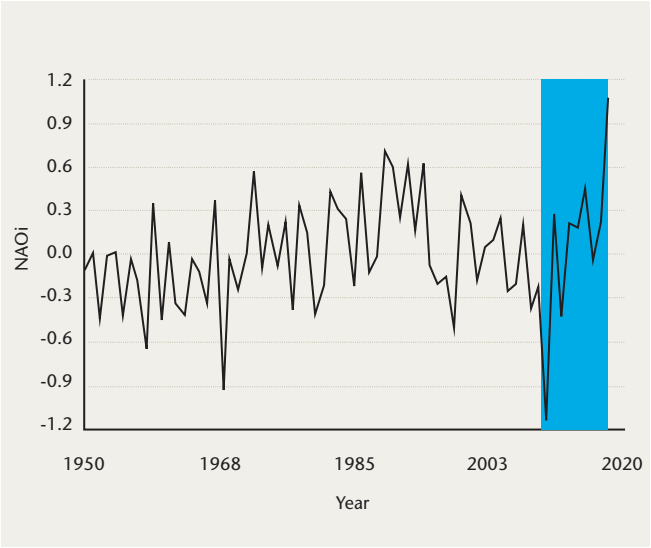

FIGURE 1: The NAO index from the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center. The line shows the annual average NAO index. The shaded area shows the time period the ACP monitored phosphorus and nitrate concentrations in Irish rivers.

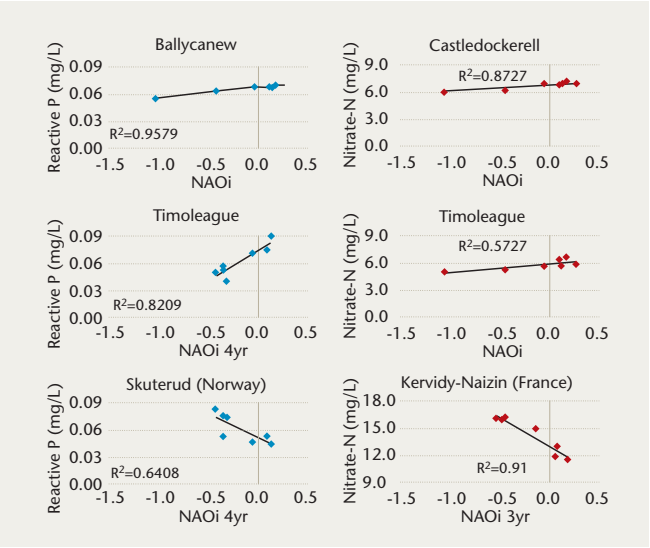

FIGURE 2: Examples of annual averages of reactive phosphorus and nitrate-N concentrations correlated to the annual average, three-year or four-year antecedent moving average North Atlantic Oscillation index (NAOi) for the period 2009-2016 in two different catchment typologies (top four positive correlations; bottom two negative correlations; third typology of catchments with no correlation is not shown).

river flow on annual cycles. The ACP collected these data from six catchments across Ireland at high resolution, and made the analysis over six years from 2009-2015. We included seven other catchment datasets from Norway and France, where there was a similar emphasis on full-data coverage, over the same time period and where weather is also potentially influenced by the NAO.

Results

When P and nitrate concentrations in catchment rivers were compared with the NAO on an annual scale, we found some with positive, some with negative and some with zero correlations, i.e., three typologies (**Figure 2**).

This means that climate has a profound impact on the state of annual river chemical water quality, at least in two catchment typologies. Furthermore, in this period of a positive NAO index, some catchments in north-west Europe may indicate a worsening of water quality (increases in annual concentration) and some may indicate an improvement. Both conditions make the job of assessing the combined influences of land use management more difficult.

The reasons for a strong climate-weather related influence on water quality are likely related to soil and geological factors and how these partition rainfall in runoff – sometimes amplifying runoff pathways into critical source areas and sometimes causing dilution.

From the analysis in this study we propose that shorter-term policy reviews take account of climate factors such as the NAO in order to gain a better understanding of cause and effect between land use, mitigation measures and water quality. This is particularly important as the NAO and other decadal-scale oceanic climate systems are likely to oscillate differently with global climate changes. Integrating catchment typologies into these reviews that account for climate-weather influences will be important and, to be robust, may require further investment in higher temporal resolution water quality monitoring in important or sensitive catchments.

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Technology driven by science

The Grange Reproductive Management Model is a decision support tool developed by TEAGASC to aid in reproductive management of suckler herds.

Sustainability within pasture-based beef cow systems is underpinned by the annual production of a live calf per breeding female and the achievement of a mean herd calving date close to the point of turnout to pasture each year. In addition to this, achieving a compact calving pattern will accrue additional benefits from the production of more uniform calf crops, such as savings in labour during routine husbandry procedures and the availability of more marketable groups of animals. However, due to the complex interaction between farm environment and animal biological cycles, farm managers often find it difficult to achieve such reproductive performance. Management decisions to achieve such targets are further complicated by the inability to robustly predict the impact a particular management strategy will have on farm performance and profitability as a whole. Given the nature of this issue, a study was commissioned to investigate the impacts of alternative reproductive management strategies on the technical and economic performance of a suckler beef herd, through the framework of a dynamic simulation model.

Impacts of reproductive management

On review of the literature, the period that occurs between calving and conception, otherwise known as the postpartum interval (PPI), was identified as a region within a suckler beef cow's reproductive cycle that was highly affected by herd management. A meta-analysis was therefore undertaken to quantify the impact of the most prominent management-related factors on the duration of this interval, focusing on body condition score of the cow at calving (BCSc), level of postpartum nutrition (PPN), level of access to the suckling calf (CA), parity of the cow post calving (primiparous or multiparous), and impact of exposure to a male stimuli pre breeding (Bexp). Results from this analysis indicated that cows managed to a correct level of nutrition pre and post calving had the potential to achieve a PPI of 52 days in duration ($P < 0.001$). However, as BCSc reduced from 2.5 to ≤ 2.25 (0-5 scale), an extension to the PPI occurred by 14 days ($P < 0.001$). This could be alleviated somewhat by increasing the level of nutrition post calving, or through the introduction of a form of biostimulation of the cow pre breeding (teaser or fence-line restricted bull). Analysis also showed that potential exists in herds that calve in an adequate BCSc (2.75), to condense their calving pattern further by implementing a temporary restriction to the suckling calf (≥ 23.5 hrs/d for six consecutive days). This strategy was indicated to be most effective at inducing oestrus activity when the calf was penned outside of both visual and olfactory range of the dam.

Dynamic model

Using the co-efficients developed from this meta-analysis, a *de novo* dynamic simulation model, known as the Grange Reproductive Management Model (GReMM), was developed to help quantify the impact of reproductive management on overall farm system performance (**Figure 1**). To construct the framework of the model, a novel system dynamics software package, 'Stella architect', was utilised. The model was sub-sectioned to allow a detailed simulation of both the gestational and PPI periods of the reproductive cycle of a herd of beef cows and ran over a period of six years. Reproductive outputs included the calving distribution of the herd, three-, six- and nine-week calving rates, calves per cow per year, and herd culling rates due to barrenness. These outputs

FIGURE 1: User interface for the Grange Reproductive Management Model (GReMM) decision support tool.

were then integrated within a whole-farm bio-economic model to assess the potential economic and environmental viability of specific reproductive management strategies.

A study was commissioned to investigate the impacts of alternative reproductive management strategies on the technical and economic performance of a suckler beef herd.

Decision support tool

Following on from the development of the GReMM simulation model, a more industry-applicable decision support tool has been developed in order to allow wider dissemination of the study findings. A user interface allows the input of current herd size, breeding season length, calving profile, replacement rate and pre-weaning mortality rate for a particular farm. Energy availability around calving is predicated on the level of concentrates fed, the silage quality, and date of turnout to pasture as indicated by the user. A number of management options can then be selected prior to the next breeding season for farmers who wish to improve upon the existing reproductive performance of their herds. These include alternative sire selection, increasing the energy density of the diet post calving, biostimulation of the cow through the use of a vasectomised bull, and temporarily restricting the suckling time of the calf from the cow.

Future editions of the GReMM decision support tool will also incorporate recent study findings on the genetic and nutritional control of puberty in beef heifers, in addition to results from trials conducted on the use of oestrus synchronisation in beef herds. A prototype GReMM decision support tool is currently being tested with advisors and farmers to ensure its adequacy in the field, with the intention for release in the coming months.

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Bone of contention

At TEAGASC, researchers examined the effects of housing and diet on cartilage condition and bone mineral density in replacement gilts.

Lameness is a major cause of poor longevity and welfare in replacement gilts. The problem is exacerbated by inappropriate housing and diet during the rearing period, and thus in recent years, there has been growing interest in improving rearing practices (e.g., Quinn, *et al.*, 2015). Unlike other countries, in Ireland replacement gilts are often reared with finisher pigs, which are destined for slaughter. As male pigs are not castrated in Ireland, replacement gilts are exposed to high levels of potentially injurious sexual and aggressive behaviour that male pigs perform as they mature. This increases the risk of injuries to the limbs and cartilage damage. Furthermore, finisher pig diets are not designed to meet the needs of developing gilts, and may not supply the necessary minerals to support good limb health, especially cartilage and bone formation and integrity. The objective of this experiment was to evaluate the effect of supplementing a finisher diet with copper (Cu), zinc (Zn) and manganese (Mn), and of rearing in female-only groups, on the locomotory ability, bone mineral density and cartilage lesion scores of gilts up to breeding age.

Experimental set-up

At weaning, maternal line gilts were assigned to either female-only pens (FEM; n = 16 pens) or mixed-sex pens (MIX; n = 16 pens), with 12 animals per pen. All gilts had the same diet, appropriate to their age, until 117.5 ± 0.6 days of age. At this point, half of each treatment remained on a standard finisher diet (CONTROL) and the other half (SUPP) received supplementary minerals (Cu, Zn and Mn). Pigs were locomotion scored (0 = perfect, to 5 = unable to move) every two weeks from 81.3 days until 165.8 days (breeding age). A sub-sample (n = 102; ≈ 25/treatment combination) were culled at breeding age and the front right limb was removed for analysis. Areal bone mineral density (aBMD) of the humerus, radius/ulna, and metatarsal bones was measured using dual energy x-ray absorptiometry. The elbow joint was then dissected to examine and score the condition of the cartilage. The humeral condyle (HC) (**Figure 1**) and the trochlear notch (TN) surface were exposed, cartilage lesions were categorised by type (**Figure 2a**) and then counted. In addition, the incidence of separation of the cartilage from the underlying bone (i.e., osteochondrosis dissecans (OCD; **Figure 2b**) was also counted (**Table 1**).

> The objective of this experiment was to evaluate the effect of supplementing a finisher diet with copper, zinc and manganese, and of rearing in female-only groups.

Results

There was no effect of either treatment on locomotory ability. In general locomotion, scores were extremely good, with only 18 pigs scoring two or more.

Bone mineral density

SUPP gilts had greater aBMD in the humerus than CONTROL gilts, and tended to have a greater aBMD in the radius/ulna. There was also an interaction between group composition and diet for the humerus. Within the SUPP treatment, FEM gilts had greater aBMD than those in the MIX groups (**Figure 2a**). The FEM-SUPP gilts also had greater aBMD than

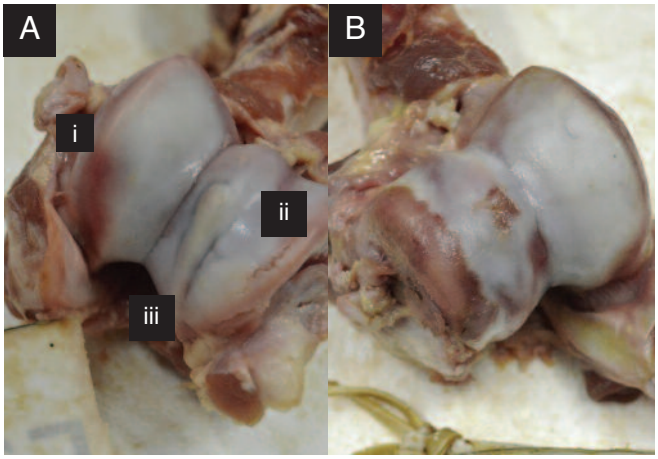

FIGURE 1: Exposed surface of the humeral condyle. Lesions that were scored included: (A) (i) thinning of cartilage, as evidenced by red bruise-like area; (ii) invagination of the cartilage; and, (iii) overgrowth; and (B) osteochondrosis lesions (separation of cartilage from the underlying bone).

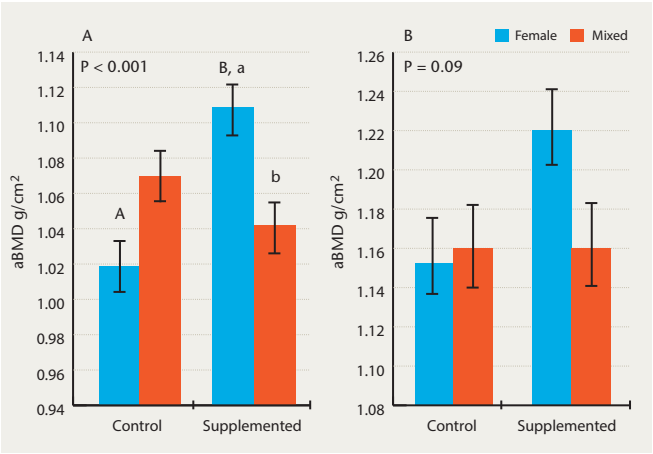

FIGURE 2: aBMD values for: (A) humerus; and, (B) radius/ulna. P-values represent the interaction effect between group composition and diet. Lower-case letters (a, b) indicate a difference of P < 0.01 between group composition within dietary treatment, whereas upper-case superscripts indicate a difference of P < 0.001 between dietary treatment within group composition.

FEM-CONTROL gilts. There was no effect of either diet or group composition on aBMD of the metacarpal.

Cartilage lesion scores

Gilts reared in MIX groups had more cartilage lesions (sum of thinnings, invaginations and overgrowths) than those in FEM groups (7.49 ± 0.3 vs 6.38 ± 0.32, respectively). When considering only the humeral condyle, where most lesions occurred, MIX gilts also had higher total scores (MIX 6.35 ± 0.31 vs 5.29 ± 0.28, respectively), and these gilts tended to have more areas of thinned cartilage. With regard to mineral supplementation, SUPP gilts tended to have fewer lesions than those in the CONTROL groups (6.49 ± 0.34 vs 7.38 ± 0.34, respectively). Fractures of the humeral condyle occurred in five gilts (4.9 % of all examined gilts), of which four were gilts reared in MIX groups. There was no effect of group composition on the number of OCD lesions. Gilts on the SUPP diet, however, tended to have a lower number of OCD lesions than those on the CONTROL diet. All gilts with more than one OCD lesion were on the CONTROL diet.

Table 1: The number of gilts reared on a standard finisher diet (CONTROL) or on a standard finisher diet supplemented with minerals (SUPP), and penned in either mixed-sex (MIX) or female-only (FEM) groups, affected by one, two or three osteochondrosis dissecans lesions in the elbow joint.

	Diet		Group composition	
No lesions present	CONTROL	SUPP	MIX[1]	FEM
1	10	11	10	11
2	3	0	1	2
3	3	0	3	0
Total no. gilts with OCD	16	11	14	13

[1] *Six males and six females per group.*

Conclusions:

- the addition of trace minerals to the diet resulted in increased bone mineral density when compared to a standard finisher diet;
- rearing gilts in female-only groups reduced the number of cartilage lesions; and,
- differences in levels of cartilage damage did not translate to differences in locomotion score; thus, alternatives to locomotion scoring to aid identification of gilts at risk of lameness are needed.

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Draining the rain

TEAGASC research has looked at different drainage system types to measure their response to extreme rainfall events.

Escalations in rainfall intensity, in terms of both volume and frequency, are increasing the variability in pasture growth and utilisation on poorly drained soils. The principal mechanism of reducing this volatility is by means of land drainage; however, the efficacy of drainage systems is widely variable, and has not been accurately quantified. Two major drainage system types exist: groundwater; and, shallow drainage designs. In a recent study, we examined the performance of nine site-specific drainage systems (five groundwater and four shallow drainage designs) during a high rainfall period. The key outcomes of interest were response times (start, peak and lag times); discharge characteristics (peak flow rate, total discharge, flashiness index, discharge hydrographs); and, water table control capacity.

Monitoring system performance

The efficiency of a drainage system is a measure of its ability to respond to rainfall events and discharge appropriate volumes of water. A review of the performance of a range of recently installed land drainage systems (on Teagasc Heavy Soil Programme farms) during a high rainfall period is required to add to the understanding of the capabilities and limitations of these systems, to generate new knowledge with respect to the efficiency of various drainage designs, and to assess their potential usefulness to improve the agronomic value of poorly drained soils. The study involved nine drainage systems across seven farms in Munster. End-of-pipe flow meters record water flow rates, while a number of in-field wells (2 m deep) with water level sensors record water table fluctuations. There is also a weather station on each farm.

The drainage system response was quantified by assessing the flow events related to a number of rainfall events. At each site, rainfall events with at least 5 mm of rainfall were selected for use in this study. Rainfall events were categorised into event types A-D depending on total rainfall amount: A = 5.0-9.9 mm; B = 10.0-19.9 mm; C = 20.0-39.9 mm; and, D = > 40.0 mm. Response was quantified according to a number of parameters such as start, peak and lag times, cumulative rain at start and peak times, flashiness index, peak flow rate, and total discharge. Across the sites rainfall was, on average, 27 % higher than the long-term average during the study period.

Drainage system response

The drainage systems were able to control the water table below the surface during the study period. Groundwater drainage designs generally maintained a deeper mean water table than shallow designs (0.82 m vs 0.53 m below ground level, respectively; **Figure 1**). Start time, peak time and lag time were not significantly affected by drainage system or drainage design type. Peak flow rate ranged from 5.5-90.2 m^3/ha per hour, and was significantly affected by drainage system and drainage design type. The average total discharge during rainfall events ranged from 100-1,722 m^3/ha.

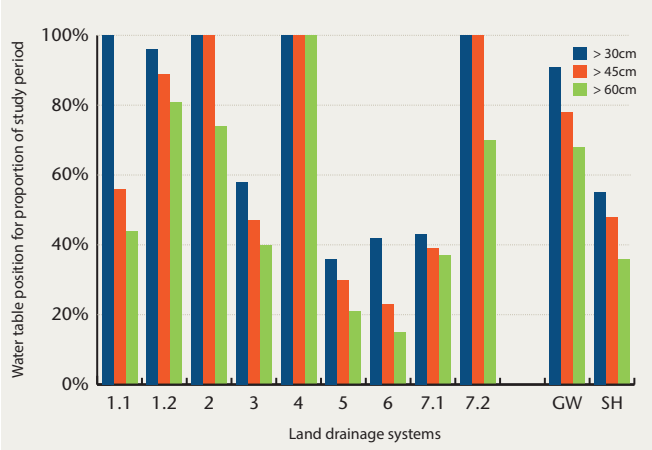

FIGURE 1: Number of days, as a percentage of total days during the study period, at which water table was below particular depths for drainage systems 1.1 to 7.2, and mean values for groundwater drainage designs (GW; 1.1-4) and shallow drainage designs (SH; 5-7.2).

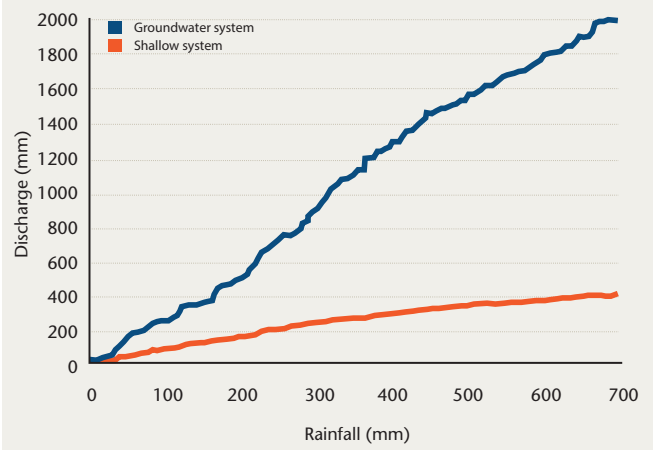

FIGURE 2: Cumulative drain discharge relative to cumulative rainfall during the study period for a groundwater drainage system and a shallow drainage system.

Groundwater drainage designs discharged significantly more water than shallow drainage designs (1,098 m^3/ha vs 189.6 m^3/ha, respectively; **Figure 2**). Start time was affected by event type, and ranged from 3.5 h (A events) to 10.8 h (C events). Peak and lag times were also affected by event type. Peak flow rate and total discharge grew with increasing magnitude of rainfall. Regression analysis identified 30-day antecedent rainfall, event rainfall and mean rainfall intensity as the principal factors affecting response times and drain discharge. Greater 30-day antecedent rainfall before the event start resulted in shorter peak times and increased peak flow rates. Greater mean rainfall intensity resulted in shorter start and peak times, and greater peak flow rates.

Factors affecting performance

All drainage systems were responsive to rainfall events. The mean start time was 6.1 h and the mean lag time was 10.4 h, and neither variable was affected by drainage system or drainage design type. Hence, similar responses were observed despite variation in soil types where appropriate drainage systems were installed. The intensity of discharge was greater in groundwater designs, as evidenced by higher peak flow rates and total discharge relative to shallow designs. This was largely due to the contribution of groundwater, which combines with infiltrating water to increase discharge levels. The location of groundwater designs in a permeable horizon relatively deep in the profile allows for direct interaction with groundwater and a larger zone of influence, and therefore base-flow is a major component of flow due to the nature of these designs. For shallow designs, flow events are almost entirely derived from the influx of surface water such that base-flow is non existent (Tuohy *et al.*, 2018). Discharge from shallow designs may also have been compromised during a rainfall event due to a reduction in the level of structural fissures and macropores that were established during installation, especially for systems reliant on mole drainage or sub-soiling. The integrity of cracks and fissures created when these systems are installed is known to reduce over time, and varies with the natural wetting/drying cycles of the soil. An increase in the efficiency of these techniques is required to maximise their performance and lifespan, and improve their potential usefulness in a more intense rainfall environment.

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Bio-waste to bio-based

The high nutritional composition of coffee silverskin makes it an excellent material for bioconversion to functional ingredients, and TEAGASC research is looking at how this might be achieved.

The Earth is projected to hold 9.6 billion people by 2050, consuming approximately 1.6 times the planet's resources and generating a consequent high amount of waste, according to the World Resources Institute. These unsustainable consumption and production patterns exhaust our resources, adversely impacting the climate, and causing air and water pollution, and loss of biodiversity and of fertile soil, among other environmental, social, and economic challenges. In spite of a general awareness that the future focus must be on prevention of waste generation, along with increased preparation for reuse and recycling as proposed under the circular economy concept, there is an urgent need to valorise waste biomass into high-value products and prevent it ending up in landfill, where it contaminates soil and groundwater and generates greenhouse gases (GHGs).

Coffee production and processing generates significant wastes throughout its life cycle stages, and if not treated properly it has critical environmental impacts as it contains caffeine, tannins and polyphenols. At an industrial scale the total quantity of coffee waste biomass generated each year globally is estimated to be around six million tonnes, while in Ireland more than 9,000 tonnes of coffee waste are produced each year, resulting in more than 11 million kg of CO_2 emissions. Most of the coffee waste is currently disposed of in landfills, where it breaks down to produce harmful GHGs, as well as hazardous pathogens and organic leachates that contaminate surface and groundwater courses. This needs to be drastically reduced, according to the EU Waste Framework Directive, 2008. Apart from this detrimental impact on the environment, all along the supply chain, much of the original coffee seed is wasted: research suggests that only about 1% of the seed biomass ends up in the coffee cup after the brewing process. Thus, the opportunity to utilise the majority of the nutrients extracted from soil during the growth stages of the coffee plant is lost. In order to develop a circular economy and the Irish bioeconomy, it is vital to ensure resource efficiency.

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Extraction of phenolic antioxidants

Research projects are currently underway in Teagasc and UCD to develop cleaner and greener pre-treatment technologies for conversion of 'bio-waste' into 'bio-based' products with potential applications in food, feed and biofuel. These projects have the potential to significantly reduce the burden on land use for protein and biofuels, not only in Ireland/Europe but worldwide, along with dramatically improving the conversion efficiencies of current bio-based production technologies. Moreover, these can significantly reduce the ever-increasing environmental problem of waste management and landfill use for waste deposition.

Under the European Union's Horizon 2020 'Waste2Fuels' project, Teagasc researchers are looking at sustainable production of bio-based products from coffee silverskin (CSS) waste. CSS is the major by-product produced during the coffee roasting process, and has started to attract interest in its bioconversion (Procentese *et al.*, 2019). Due to its high nutritional composition (**Table 1**), CSS is being considered as a source of functional ingredients, such as antioxidant compounds

or supplements of soluble dietary fibre. In this work, both simultaneous ultrasound/microwave-assisted (S-UMAE) and sequential ultrasound-microwave assisted aqueous extraction methods (U-MAE and M-UAE) are applied and compared with their individual techniques (UAE alone and MAE alone). The results indicate that S-UMAE showed greater potential and better extraction efficiency for phenolic antioxidants from CSS, compared with UAE, MAE, U-MAE and M-UAE. S-UMAE achieved 25.9 %, 16.7 %, 13.1 % and 12.8 % higher extraction yields than UAE, MAE, U-MAE and M-UAE, respectively. Additionally, the yields of total phenolic content and antioxidant capacity were enhanced significantly by S-UMAE compared to other methods. It was concluded that with the help of novel extraction technology, CSS extraction, with water as solvent, can enhance the extraction performance in a green and sustainable way, and combinations of these extraction technologies could accomplish a balance between extraction efficiency, product quality, consumption of solvent, and production costs in the industry.

Under the European Union's Horizon 2020 'Waste2Fuels' project, Teagasc researchers are looking at sustainable production of bio-based products from coffee silverskin waste.

Table 1: Nutritional and mineral composition of coffee silverskin (data expressed as g per 100 g of dry weight).

Coffee silverskin composition (g/100 g)	
Moisture	5.89 ± 0.46
Protein	14.62 ± 0.23
Fat	3.60 ± 0.29
Ash	3.47 ± 0.39
Dietary fibre	64.45 ± 1.63
Insoluble fibre	54.7 ± 0.85
Soluble fibre	9.75 ± 0.78
Carbohydrate	7.97 ± 0.44
Macrominerals	
Calcium (Ca)	1.48 ± 0.05
Potassium (K)	1.21 ± 0.04
Magnesium (Mg)	0.05 ± 0.01
Sodium (Na)	0.05 ± 0.01
Iron (Fe)	0.04 ± 0.01

Commercial perspective

The real benefit of these projects, and their value for primary producers, will not be realised unless there is potential for industrial applications, and this calls for understanding the market for the end product and conducting techno-economic analysis of the procedure, which, when a technology or process is being developed, ensures that market-driven prices can be achieved (Priyadarshini *et al.*, 2018). With its components embedded in research and development of the process, techno-economic analysis and market assessment are invaluable, direction-steering tools. Therefore, the proposed next step in the projects being explored with researchers in TU Dublin, is conducting a costing analysis of the process to quantify the associated life cycle costs and scale-up potential. Market assessment of the end product is also needed, including its current production, manufacturers, product selling prices, product marketing, competing and substitute products, and customer analysis (such as: feed, food ingredient and food supplements manufacturers).

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The value of seaweed

TEAGASC researchers are developing zero waste industry processes to generate high-value-added products from seaweed.

Biorefinery concept

Depletion of natural resources and climate change, together with increased food needs for a growing global population, are priority economic and environmental issues. These sustainability issues are currently being addressed by the food and feed industries, which are modifying their current practices to develop novel bio-based and more sustainable processes and products, and using natural resources such as seaweed as a source of multiple chemicals and fuel production. Biorefineries, which are facilities that integrate biomass conversion processes and equipment to produce fuels, energy, and value-added chemicals from biomass, are increasingly being employed. Biorefineries exploit natural resources for the production of energy while improving the efficiency of industrial processes, reducing energy consumption, and increasing the production of multiple high-value-added products from raw materials. Following this production system, the waste of one process is sequentially used as an input for another process, with the aim of achieving zero waste production and generating additional benefits from both economic and environmental perspectives (Balina *et al.*, 2017).

Potential of seaweed

The use of seaweed or macroalgae offers huge opportunities for the development and exploitation of biomass through adoption of a biorefinery model. Seaweed are aquatic organisms that live attached to any hard surface on coastal areas and can be classified into three main groups, primarily on the basis of colour: red seaweed or Rhodophyta (over 7,200 species); brown macroalgae or Phaeophyta (about 2,000 species); and, green algae or Chlorophyta (>1,800 species). Moreover, seaweed from different groups can also be differentiated on the basis of structural and biochemical composition, including special types of pigments, polysaccharides, and other bioactive compounds (Garcia-Vaquero *et al.*, 2017). Due to the varied composition of seaweed, this biomass has traditionally been used for multiple agricultural applications, including soil fertilisers and animal feed. The use of seaweed for food applications started over 2,000 years ago, when the Japanese included macroalgae in their daily diet, and over the years the popularity and use of seaweed as an additive in a wide spectrum of foods such as confectionery, canned fish products, snacks and beverages has increased. Moreover, the potential of seaweed to generate energy and store carbon resources has also been exploited by industry to generate biofuel, biogas, biodiesel and bioethanol. Seaweed biomass is easily available for use by the biorefinery industry and the collection of invasive species to produce energy in different coastal areas may reduce the negative environmental impact of these damaging algae. In addition, following the

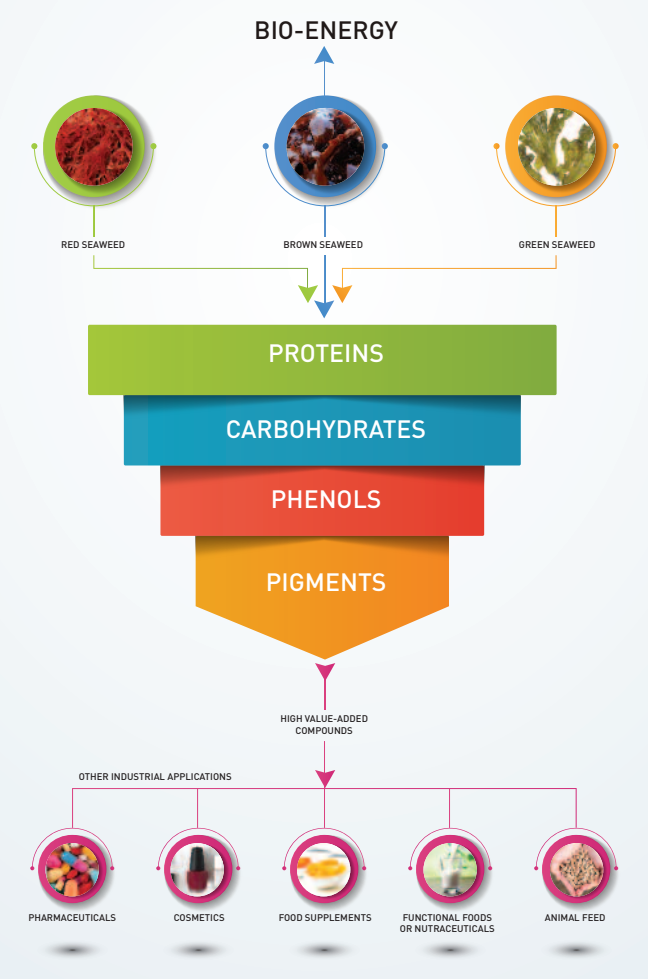

FIGURE 1: Schematic outlining the use of seaweed in a biorefinery model to produce energy and multiple high-value-added compounds.

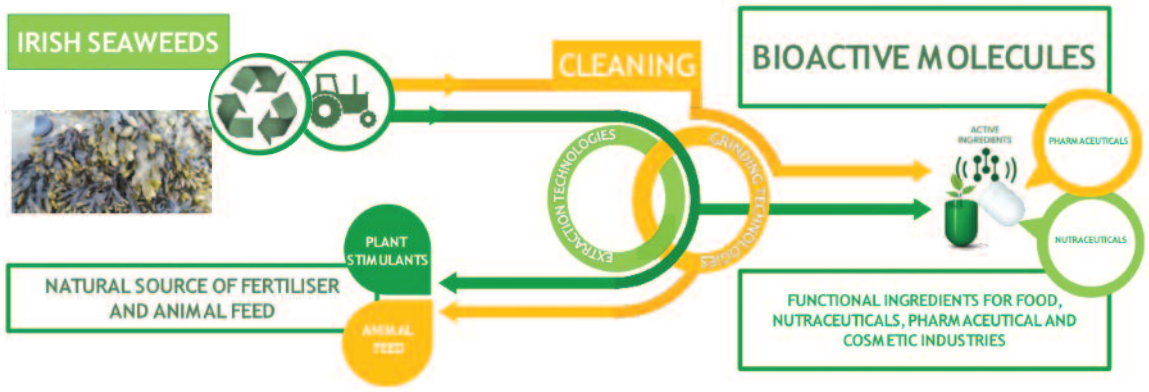

FIGURE 2: Teagasc research is improving the efficiency of industrial processes to produce high-value compounds from seaweed.

biorefinery concept, the biomass will be converted into energy, and intermediate products will also be utilised and transformed into high-value-added products, achieving higher economic benefits than when focusing on attaining a single compound or product. Following the production of energy, the seaweed biomass still contains valuable compounds such as polysaccharides, phenolic compounds, proteins and other small molecules, with multiple biological properties including antioxidant, anti-cancer, anti-tumour and immunomodulatory activities. These are useful in a wide variety of industrial applications such as pharmaceuticals, cosmetics and nutraceuticals (**Figure 1**). For example, phenolic compounds such as phlorotannins have powerful anti-inflammatory, anti-diabetic, antioxidant and anti-bacterial properties. Polysaccharides from seaweed have been shown to be a promising source of biologically active compounds for multiple biomedical applications. Fucoidans from brown macroalgae possess antiviral, anti-inflammatory, anti-angiogenic, anti-cancer and anti-hyperglycaemic effects, while other carbohydrates such as alginates and carrageenans are used for their physical properties. Alginates are currently used in the textile, paper and biomedical industries, while carrageenans are frequently employed in the meat and dairy sector due to their gelling, thickening and stabilising properties.

This wide variety of benefits, high-value molecules and potential applications has recently focused the attention of consumers and industries (pharmaceutical, cosmetic and nutraceutical), which are producing an increased range of products containing seaweed or seaweed compounds, such as health supplements, cosmetics and functional foods (Garcia-Vaquero *et al.*, 2017; Hayes *et al.*, 2015).

Current state of seaweed biorefinery

Researchers at Teagasc are improving the efficiency of the industrial processes to produce high-value compounds from seaweed, by utilising wastes and seaweed by-products (**Figure 2**). Within the SFI Bioeconomy Research Centre 'BEACON' project, Teagasc researchers are currently exploring the use of novel and more efficient technologies, including ultrasound and microwave technology, to obtain carbohydrates or phycocolloids (i.e., alginates), while sequentially exploiting the remaining biomass to recover other bioactive compounds (i.e., proteins, pigments and polyphenols) and transforming the remaining waste into biofuel or biofertilisers. This exploitation model aims to achieve a sustainable and zero waste phycocolloid industry and more efficient industrial extraction processes.

Acknowledgments

The authors are grateful for funding from the SFI Bioeconomy Research Centre 'BEACON' project.

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Blending dairy and cereal

Fermented dairy-cereal blends present a new potential for Irish ingredients and TEAGASC and UCC researchers have been researching the development and characteristics of different blends.

The benefits of dairy-cereal blends as foods

Cereal and dairy constitute two of the five major food groups, with the average respective proportions of each, as a percentage of total food consumed per person, varying from an estimated 18.6 % and 6.2 % in developing countries to 10.2 % and 12.4 % in developed countries. They are frequently combined to create blends or composites, which provide a means of innovating products with the additive nutritional, textural and sensory functionalities of both food groups. The addition of milk solids to cereal-based products enhances the content of important nutrients, including essential amino acids, linoleic acid, fat-soluble vitamins, calcium and phosphorous. Fermentation of the dairy components (e.g., fermented milk) enhances the nutritional status by increasing the bioavailability of cationic elements such as calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu) and iron (Fe), promoting the release of bioactive peptides encrypted within the casein, increasing the levels of essential amino acids and B vitamins, and reducing the lactose content. Conversely, the addition of cereal, such as oats, wheat or barley, to dairy-based beverages imparts viscosity/texture, and enhances the content of dietary fibre, including β-glucan, to a degree dependent on the type of cereal and its pre-treatment prior to blending. Research suggests that the inclusion of β-glucan in the human diet reduces the glycaemic index, blood cholesterol and the incidence of coronary heart disease, and improves gastrointestinal function. Consequently, fermented milk-cereal beverages are being increasingly promoted for their nutritional benefits – https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2019090119&tab=PCTBIBLIO. However, phytic acid (inositol-phosphate) in cereals chelates multivalent cationic metals including Fe, Zn and Ca, and can thereby reduce their absorption in the gastrointestinal tract and increase the risk of mineral deficiencies in humans and other monogastric animals that lack the phytase enzyme.

The addition of milk solids to cereal-based products enhances the content of important nutrients, including essential amino acids, linoleic acid, fat-soluble vitamins, calcium and phosphorous.

Commercial dairy-cereal blends

Commercial examples of dairy-cereal blends include yoghurt-cereal bars, co-fermented dairy-cereal beverages, nutritional snack biscuits/bars, and dehydrated blends such as Super Cereal Plus (SCP), kishk and tarhana, which may be reconstituted to prepare fortified blended foods (FBFs), nutritious soups or beverages. SCP, a

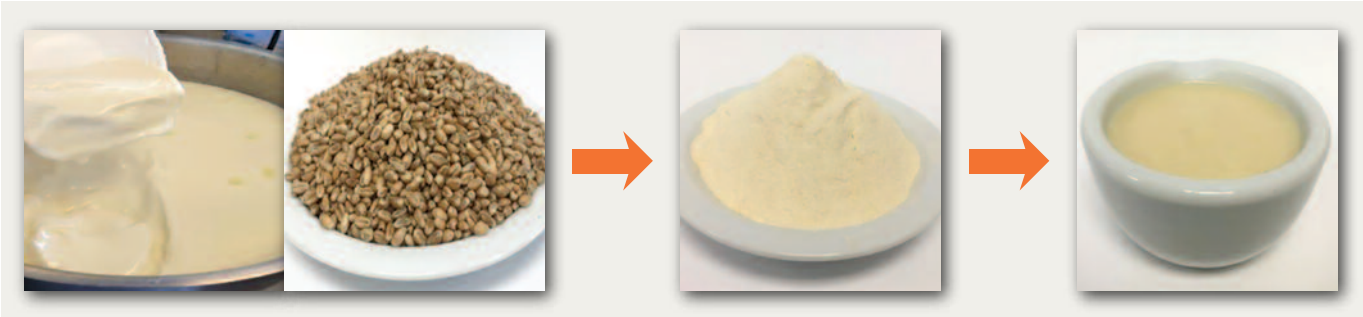

FIGURE 1: Fermented milk plus cereal giving a fortified blended food powder that is reconstituted and cooked to make a nutritional dish.

category of FBF supplied by the World Food Programme, is designed to improve the diet of young children, aged six to 59 months, in food-insecure regions. It is a powdered product formulated by dry blending heat-treated wheat, dehulled soya bean, sugar, skim milk powder, refined soya bean oil, and a vitamin/mineral mixture. Kishk is a dried fermented milk-/cereal-based product that has been traditionally consumed in the Middle East, where it is reconstituted and cooked to form a porridge or soup, or used as an ingredient in savoury and sweet dishes. Tarhana, a dehydrated fermented milk/cereal product of Turkey and Greece, resembles kishk but differs in its formulation, whereby parboiled wheat is substituted by wheat flour, and baker's yeast (*Saccharomyces cerevisiae*), and diced vegetables and spices are included as additional ingredients.

Studies at Teagasc Moorepark and UCC

Development of fortified blended foods using dairy-cereal blends

A collaborative project between Teagasc Food Research Centre, Moorepark, and the School of Food and Nutritional Sciences in UCC has, since 2015, been researching the development and characterisation of FBFs based on Irish-sourced dairy ingredients and cereals. The developed process involves a series of steps: de-hulling, parboiling and milling the cereal; blending fermented milk (~17 % dry matter [DM]) and parboiled cereal (~94 % DM) at a weight ratio of 2.9-4.4:1 (depending on the protein content of the cereal); co-fermentation of the blend at 35 °C for 24-72 h; shelf-drying at 46 °C; milling to a particle size of ≤ 1 mm; fortification with vitamins, minerals and essential free fatty acids; vacuum packing in PE60/Met shrink pouches; and, storage (**Figure 1**). Parboiling of the cereal and co-fermentation of the fermented milk-cereal blend were adapted as strategies to reduce phytic acid content.

The FBFs are a rich source of protein, essential amino acids, fatty acids, vitamins, minerals, antioxidants, β-glucan and lutein. Key factors affecting the composition (and hence nutrient value) and consistency/viscosity characteristics of the reconstituted FBFs have been identified: cereal type; fermented milk-to-cereal ratio; co-fermentation time; and, storage conditions. Most notably, FBFs made with oats instead of wheat had higher contents of starch, β-glucan, lysine and Fe, and lower levels iodine (I), Mg and Zn, were thicker and tackier during cooking, and were more prone to becoming stiffer and stodgy after cooking. Overall, the consistency of oat-based FBFs was porridge like, while that of wheat- or barley-based FBFs was more fluid and soup like.

Increasing the ratio of fermented milk-to-cereal coincided with higher contents of protein, lactose, fat, Ca, Zn, P, and vitamins A and E, lower contents of phytic acid and β-glucan, and lower viscosity after reconstitution and cooking. Increasing the fermentation time from zero to 72 h reduced the quantities of phytic acid and lactose, and the viscosity during, and after, cooking the reconstituted FBF. The FBF powders were quite stable on storage at 15 °C for up to 18 months; conversely, storage at 30 °C or 37 °C led to deterioration in essential fatty acids, colour, vitamin C or E activities, antioxidant activity and reconstitution behaviour of the FBFs, to a degree affected by storage time and cereal type.

Product opportunity/benefit

The project findings provide new know-how and insight into the design of innovative food products (e.g., powdered FBFs, beverages) combining the nutritive, techno-functional, and flavour properties of dairy and cereal. Such products present a new export opportunity for Irish-based dairy ingredients and cereals.

Acknowledgement

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The 'language' of farming

Research from NUI Galway and TEAGASC is giving voice to the older farmer's position in the generational renewal narrative.

Introduction

The senior generation's reluctance and indeed resistance to alter the status quo of the existing management and ownership structure of their family farm is undoubtedly strong within the farming community. This phenomenon has resulted in extraordinary socio-economic challenges for young people aspiring to embark on a career in farming. The reasons why older farmers fail to plan effectively and expeditiously for the future are expansive, and range from the potential loss of identity, status and power that may occur as a result of engaging in the process, to the intrinsic multi-level relationship farmers have with their farms. These so-called 'soft issues', i.e., the emotional and social dimensions involved, are the issues that distort and dominate the older generation's decisions on the future trajectory of the farm. These really are the 'hard issues'. The full report on this study, published in the *International Journal of Agricultural Management* (Conway *et al.*, 2019), draws on three interrelated journal articles exploring the complex human dynamics influencing the decision-making processes surrounding farm succession and retirement published by Conway *et al.* (2016; 2017; 2018) to put forth a series of recommendations that sensitively deal with problematic issues surrounding generational renewal in agriculture, while also ensuring farmers' emotional well-being in later life.

Data collection

Conway *et al.* (2016; 2017; 2018) employed a multi-method triangulation design to obtain an in-depth, holistic understanding of the various facets governing the attitudes and behaviour patterns of older farmers towards the intergenerational farm transfer process. Questionnaires were initially distributed to a randomly selected sample of farmers in attendance at a series of 'Transferring the Family Farm' clinics delivered by Teagasc in 2014, held at 11 locations throughout Ireland (n = 324). A list of copyright questions derived from the International FARMTRANSFERS Survey, refined for Irish conditions, were then included in the 2014 Teagasc Land Mobility Farm Survey to validate, strengthen reliability and build on the quantitative data gathered at the clinics (n = 309). Finally, interviews were conducted with a 10 % sample of questionnaire respondents, who gave their consent to be interviewed, in order to peel back the layers and broaden the two farmer survey responses (n = 19).

> These so-called 'soft' issues, i.e., the emotional and social dimensions, are the issues that distort and dominate the older generation's decisions.

Policy recommendations

The following recommendations are aimed at allowing older farmers to maintain and sustain existing activities and daily routines on their farms in later life, while also 'releasing the reins' to allow for the necessary delegation of managerial responsibilities and ownership of the family farm to their successors, in order for generational renewal to occur.

Recommendation 1:
Farmer-sensitive policy design and implementation
Conway *et al.* (2016) found that policy strategies put in place over

the past four decades, designed to encourage older farmers to retire, had little or no regard for their emotions and were preoccupied with financial incentives to encourage the process. This study recommends that any new initiatives to support/encourage the process should not be conceived so narrowly as to ignore possible social consequences or wider issues of human dignity. Both emotional and economic needs must be catered for, and ideally a policy for structural reform in agriculture must be accompanied by a comprehensive set of interventions to deal with the personal and social loss an older farmer may experience upon transferring the family farm. For example, on its own, and with the numerous perceived negative connotations associated with it identified, the term 'Early Retirement Scheme' is no longer appropriate language for policymakers to use in a farming context. Perhaps the term 'Farm Progression Scheme' would be more effective as it portrays a sense of purposefulness rather than one of cessation.

Recommendation 2:
Farm succession facilitation service
Conway *et al.* (2017) discovered that the senior generation employs an intricate array of complex strategies and practices of power and control in an effort to galvanise and sustain their positional dominance as head of the family farm. This study advocates that the services of a certified farm succession facilitator, trained in accordance with an international best practice model, such as the one offered by the International Farm Transition Network (IFTN) in the USA, is essential, particularly when facilitating communication and discussions between family members' objectives, goals and expectations for the farm.

Recommendation 3:
Establishment of a national voluntary organisation for older farmers
As there are no NGOs or services currently in existence in Ireland that represent the needs and interests of the older farmer in rural areas, this study recommends the establishment of a national voluntary organisation that represents the needs of the senior generation of the farming community, equivalent to that of younger people in rural Ireland, i.e., Macra na Feirme. Conway *et al.* (2018) found that a significant obstacle to the farm transfer process is the rigid inflexibility of the occupational role, where farmers wish to remain 'rooted in place' on the farm and, in many cases, have developed few interests outside of farming. Such a voluntary organisation, funded annually by the Government and through membership, would provide farmers with a support around which they could remain embedded inside their farms and social circles in later life.

Recommendation 4:
Occupational health and safety in agriculture awareness
On a related aspect, the insight into the intrinsic link to farmer-farm attachment in later life and the importance attributed to the habitual routines within the farm setting obtained by Conway *et al.* (2016; 2018) will provide the Health and Safety Authority (HSA) with an invaluable understanding of the various actions taken by (or that should be taken by) older farmers to handle age-related physical limitations and barriers on their farms. This knowledge will aid in the development of an effective health and safety service tailored specifically to the needs of older farmers.

Acknowledgements

We are grateful to the farmers who took part in this research. Funding was provided by the NUI Galway Doctoral Research Scholarship Scheme. We would also like to thank Teagasc for its assistance with this research, in particular for allowing us to conduct surveys with farming clients.

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Farmer perceptions of risk in farm succession

TEAGASC research has found that economic and financial concerns are a significant barrier for older farmers in terms of succession and farm transfer planning.

The process of land transfer to the next generation can be a cause of concern for farmers and successors alike. Land transfer can be considered to have three stages, with succession, inheritance and retirement each representing key phases in passing on the land to the next generation. Succession refers to the handing over of managerial control from the operator to a successor, and inheritance denotes the legal transfer of assets from the operator to a successor, while retirement indicates the exit of the operator from farming. Many farmers in Ireland rarely enter full retirement, but often enter a stage of semi-retirement in which they remain involved in the day-to-day running of the farm.

Current Government initiatives to promote young farmer entry include a 25 % top-up on the Basic Farm Payment for farmers aged 40 and under, and reliefs on Capital Acquisitions Tax, Capital Gains Tax, and Stamp Duty. Despite these incentives, 30 % of farmers in Ireland are aged 65 years and over (CSO, 2018), indicating that land mobility in Ireland remains low.

Teagasc research

In 2018 Teagasc conducted research focused on farmer decision making with regard to farm transfer. This involved interviews with 24 farmers in counties Cork and Mayo. A total of 8 % of farmers in Cork were aged under 35, while a low percentage were 65 and over (20 %). By contrast, Mayo had the lowest percentage under 35 (4 %) and the highest percentage of farm operators aged 65 and over (33 %) (**Figures 1** and **2**). In addition to demographic differences, farm systems also differ, with dairy being a prominent system in Cork, while Mayo has a high number of beef (cattle rearing and cattle other) farms. These farm systems differ significantly with regard to income: average family farm income for dairying stands at €66,788, while cattle-rearing systems accrue €12,568 on average (three-year average for period 2015-2017 using Teagasc National Farm Survey data). All dairy farmers interviewed were full-time farming, while all but two of the beef farmers interviewed either worked off farm or had retired from off-farm employment. The main issues raised by farmers interviewed for this research are summarised below.

Capital taxation

Farmers who were interviewed had varying opinions with regard to capital taxation. Generally, opinions on capital taxation differed by farm system. Those involved in beef farming were concerned about the negative effect that capital tax would have on both themselves and their successor.

On the contrary, dairy farmers felt that planning in advance of farm transfer would avoid any negative effects stemming from capital tax. Dairy farmers cited regular contact with a professional (accountant or farm advisor) as a key element of their financial planning with regard to land transfer to the next generation. Beef farmers who were interviewed had less contact with professionals.

Marital breakdown

One core concern raised by dairy farmers was risk of successor marital breakdown. A majority of dairy farmers interviewed highlighted that they were reluctant to transfer the farm to their successor because of the possibility that their successor would get divorced and the farm would have to be sold or split. In some cases farm successors did not have partners, but the issue remained to the forefront for the farmers regardless. Some interviewees noted the possibility of a pre-nuptial agreement as a solution to this problem; however, agreements of this nature generally have no legal standing in these instances.

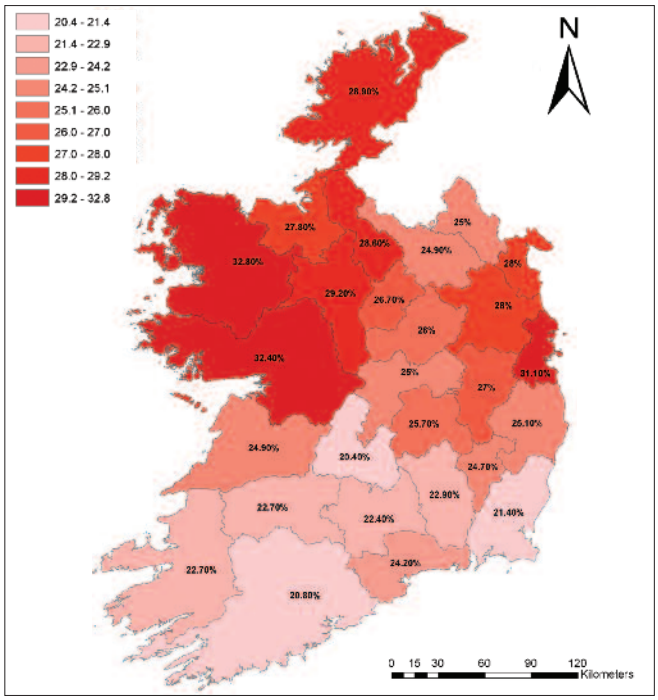

FIGURE 1: Farmers aged 65 and over by county. Source: CSO 2012 data.

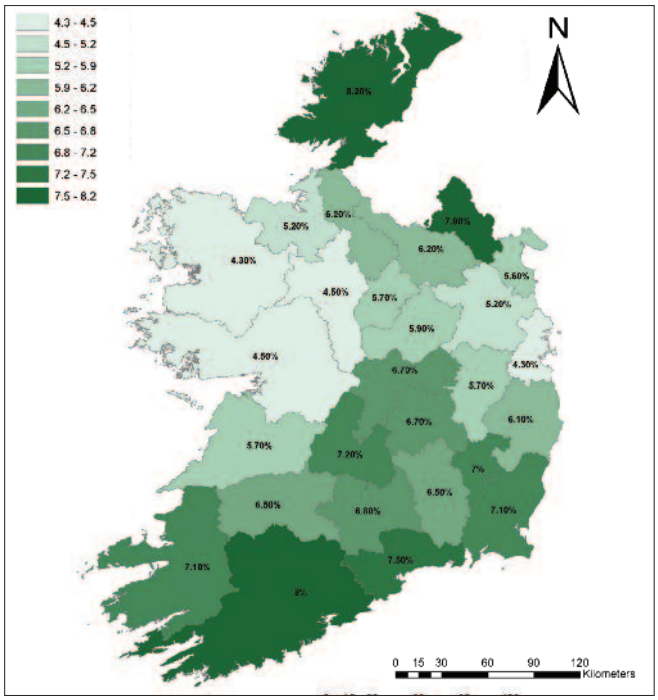

FIGURE 2: Farmers aged under 35 by county. Source: CSO 2012 data.

Retirement income

Similar to taxation, farmers had differing views regarding retirement income. For dairy farmers, retirement income took the form of a private pension, which they contributed to over time from the income they made from farming. However, beef farmers faced the possibility of being dependant on a contributory State pension. For these farmers, the low income from farming in old age was required to provide for them financially later in life.

Cost of long-term care

The final issue raised by interviewees was that of long-term care costs. Here, both beef and dairy farmers had similar concerns. The unpredictability of long-term care needs, together with the high cost of nursing home care, contributed to farmer reluctance to engage in land transfer processes. At the centre of this was the possibility that a successor would come under serious financial pressure to pay for long-term care, resulting in the failure of the business and eventual sale of the farm. Several farmers noted the inability of State efforts such as the Fair Deal scheme to assist members of the farming community with long-term care costs.

Recommendations

A key element of the results presented here is the reluctance of farmers to engage in generational land transfer due to economic factors. Ensuring financial security for farmers intending to retire (or semi-retire) must be a central aspect of future generational renewal policy in order to encourage the timely entry of younger farmers to the sector, while also facilitating the gradual exit of outgoing farmers. This may take the form of dissemination of knowledge regarding current capital taxation reliefs. Additionally, a State pension top-up for those who do not have private pensions could provide a source of financial security for those considering handing the farm over to the next generation.

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SEPTEMBER

September 27
Cork City (multiple venues)

CORK DISCOVERS – A WORLD OF RESEARCH

Teagasc is a partner in this series of free and exciting interactive events for all ages. Come and join us to explore topics ranging from archaeology to zoology, and learn how research impacts on your daily life. Cork Discovers is funded by the European Union's Horizon 2020 programme as part of European Researchers' Night. This initiative celebrates researchers and the valuable contributions that they make to our society, with over 100 researchers participating in events on the UCC campus and in other venues in Cork City last year. This year's event promises to be even more exciting!
Contact: kim.reilly@teagasc.ie
http://corkdiscovers.org/

September 30 *Teagasc Food Research Centre, Ashtown, Dublin*

NEW RESEARCH AND INDUSTRY PERSPECTIVES IN SENSORY SCIENCE

This event offers unique learning and networking opportunities, with insights covering new sensory research dimensions coupled with relevant industry case studies involving SMEs and multinational food companies. Organised by Sensory Food Network Ireland, the event will highlight research and industry-focused sensory activities within the network.
Contact: SensoryFoodNetworkIreland@teagasc.ie
https://www.teagasc.ie/news--events

OCTOBER

October 16 *Teagasc, Oak Park, Carlow*

TEAGASC FOREST RESEARCH DAY

This outdoor event will be an opportunity to see the role of forest research in contributing to addressing the challenges and opportunities across many aspects of forestry and forest management in Ireland. The following research topics will be highlighted: broadleaf tree improvement; birch and alder; broadleaf silviculture; ash restocking options; sitka spruce provenance trials; alternative conifers; thinning conifers; ash dieback resistance breeding; integrated pest management (IPM) of pine weevil; and, continuous cover forestry (CCF). This Forest Research Day is approved as a Forestry KTG event.
Contact: frances.mchugh@teagasc.ie
www.teagasc.ie/crops/forestry/news/2019/teagasc-forest-research-day-2019.php

NOVEMBER

November 5-7 *Clayton Whites Hotel, Wexford*

CATCHMENT SCIENCE 2019

This international conference focuses on achieving quality water in diverse and productive agricultural landscapes under a changing climate. The themes are: soil analysis and nutrient management; drivers, controls and time lags – meeting the expectations; options for management approaches in reducing nutrient loss risk; long-term in-situ monitoring and modelling of water quality; impacts of multiple stressors on aquatic ecology; decision support tools; integrated management, stakeholder engagement and catchment economics; knowledge transfer; and, water governance and policy implementation. The event includes a poster session, gala dinner and field visits.
Contact: pererik.mellander@teagasc.ie
https://www.teagasc.ie/news--events

November 10-17 *Locations nationwide*

FESTIVAL OF FARMING AND FOOD – SFI SCIENCE WEEK AT TEAGASC

This festival is a celebration of the science underpinning sustainable agriculture and food production in a series of events aimed at a broad audience ranging from primary school students up to open events for the general public. The theme of this year's Science Week is climate action. Attendees will learn about a wide variety of topics and how they apply to their everyday lives, including: sustainability of animal and plant production; healthy soils and biodiversity; the development of rural areas; food for health; food product development and improvement; and, food safety. There will be plenty of opportunities to participate in hands-on experiments and demonstrations.
Contact: catriona.boyle@teagasc.ie
http://www.sfi.ie/engagement/science-week/

November 19 *Teagasc Food Research Centre, Ashtown, Dublin 15*

BRIDGING SCIENCE AND THE CONSUMER: KEY MARKET TRENDS AND IMPLICATIONS FOR THE IRISH FOOD INDUSTRY

This one-day conference, jointly organised by Bord Bia and Teagasc, will gather representatives from industry, research, farmers, Government and public sector agencies, and others who are concerned with the future direction of the Irish food industry. It will feature presentations on the results of market-based research undertaken by Bord Bia, scientific research undertaken by Teagasc and invited international speakers. MC Jonathan McCrea will chair a panel discussion that will reflect on these presentations to identify future implications for the Irish food industry. The conference will provide a forum to discuss and debate actions that will be critical to ensuring a competitive food industry for the future.
Contact: bridin.mcintyre@teagasc.ie; maeve.henchion@teagasc.ie
https://www.teagasc.ie/news--events

November 21 *Teagasc Food Research Centre, Moorepark*

FOOD INNOVATION GATEWAYS: FOOD BIOTRANSFORMATION – BIOLOGICAL PROCESSES FOR SUSTAINABLE FOOD DEVELOPMENT

The forthcoming Teagasc Gateways event will showcase the latest biological biotransformation processes in a range of food and beverage applications, as well as highlighting capability and expertise within Teagasc and Moorepark Technology Centre in this area.
Contact: kieran.kilcawley@teagasc.ie

For a full list of Teagasc food industry training events see:
https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/.
For presentations from previous Teagasc events see: www.teagasc.ie/publications.